From:	Purdy, Sandra FLNR:EX
To:	Jones, Tristan FLNR:EX; Parmar, Ravi FLNR:EX; McLaren, Kenn FLNR:EX; Renneberg, Tim FLNR:EX
Cc:	Silverio, Lisa FLNR:EX
Subject:	Glyphosate Report and Info Note
Date:	Monday, December 23, 2019 10:02:40 AM
Attachments:	252744 ATT 2 - FPInnovations - Glyphosate Use in BC Forestry - Final 20191211.pdf 252744 MDD BNI - FPI Glyphosate Review Report.pdf 252256 ATT 1 - ADM BNI - Summary of FPI Glyphosate Review Report.pdf

---

See attached for your information. I've sent to MDD.

FPInnovations

info@fpinnovations.ca
www.fpinnovations.ca

REVIEW OF GLYPHOSATE USE IN BRITISH COLUMBIA FORESTRY

PROJECT NUMBER: 301013763

Jim Hunt, Lead Scientist

Pamela Matute, Researcher

November 2019

FPInnovations

The present is a review of current glyphosate use in British Columbia forestry, peer-reviewed forest science on the impacts of glyphosate use on forests, and input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in British Columbia was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishing forest stands post-harvest.

Project number: 301013763

ACKNOWLEDGEMENTS

This project was contracted by the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development

APPROVER CONTACT INFORMATION
Shawn Hedges
Director, Sustainability and Forestry

shawn.hedges@gov.bc.ca

REVIEWERS
Ken Byrne, Manager, Fibre Supply

AUTHOR CONTACT INFORMATION
Pamela Matute
Researcher, Fibre Supply
pamela.matute@fpinnovations.ca
(604) 222-5698

Disclaimer to any person or entity as to the accuracy, correctness, or completeness of the information, data, or any analysis thereof contained in this report, or any other recommendation, representation, or warranty whatsoever concerning this report.

Follow us

Table of contents

Executive Summary 1
1 Introduction 3
2 Use of Glyphosate in British Columbia Forests 4
2.1 Regulatory Framework 4
2.1.1 Free Growing 4
2.1.2 Herbicides 5
2.2 Why is Glyphosate Used? 6
2.2.1 Site Preparation 7
2.2.2 Plantation Survival 7
2.2.3 Crop Tree Productivity 7
2.2.4 Invasive Species 7
2.3 How is Glyphosate Used? 8
2.3.1 Area Treated 8
2.3.2 Glyphosate Use at the Stand Level 11
2.4 Treatment Costs 13
3 Impact of glyphosate use on non-timber values 14
3.1 Biodiversity 14
3.1.1 Broadleaf Tree Species 14
3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide treatment 14
3.1.1.2 RESULTS analyses 15
3.1.2 Non-Target Plant Communities 16
3.1.3 Aquatic Organisms 17
3.1.4 Wildlife 18
3.1.4.1 Toxicity 18
3.1.4.1 Forage quality and quantity 18
3.2 Soil and Water Quality 19
3.2.1 Glyphosate/aminomethylphosphonic acid fate in soils 19
3.2.2 Soil microorganisms 20
3.2.3 Glyphosate/aminomethylphosphonic acid fate in water 20
3.3 Climate Change 21

3.4 Wildfire 21
3.5 First Nations 22
3.6 Public Use 23
4 Impacts on Timber Supply 24
4.1 Managing for Multiple Values 25
5 Recommendations 26
6 Conclusions 27
7 References 28
Appendix 1. International Assessments 40
Appendix 2. Stocking Standards and Survey Changes Related to Deciduous Management in British Columbia 43
Appendix 3. Integrated Pest Management Principles 44
Glossary 51

EXECUTIVE SUMMARY

FPInnovations was contracted by the Office of the Chief Forester to undertake a review of current glyphosate use in British Columbia (B.C.) forestry including peer-reviewed forest science on the impacts of glyphosate use on forests, and input from stakeholders. The use of glyphosate in relation to the multiple values that are pertinent to forest management in B.C. was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishing forest stands post-harvest. The report will inform future policy development and research needs, with the main objective to promote the establishment of healthy and diverse forests.

The herbicide glyphosate is one of many vegetation management tools available to forest managers. As a tool for vegetation control, it is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. It is very effective because it is easily translocated within the target plant, and usually kills it and reduces the brush hazard for multiple years after a single application, unlike other motor-manual vegetation control methods. Glyphosate application may target aggressive competition from broad-leaved trees, shrubs, and herbaceous vegetation.

In 2018, approximately 11,000 ha of Crown land in B.C. were treated with glyphosate for silvicultural purposes. The total area treated with glyphosate was 7% of the area harvested on B.C. Crown land in 2018, and less than 0.5% of the area with outstanding reforestation obligations. In 2018, most (73%) of the glyphosate application was conducted in the Omineca Natural Resource Region. Of all the biogeoclimatic zones, the Sub-Boreal Spruce zone received the most glyphosate application (76%). Glyphosate was applied primarily aerially (86%); the remainder (14%) was applied using ground-based methods.

Public concerns over the impacts of glyphosate use on the ecosystem are growing, particularly regarding ecosystem changes resulting from the control of broadleaf trees such as trembling aspen. A RESULTS (Reporting Silviculture Updates and Land Status Tracking System) analysis of deciduous stand components at free growing showed that in the Omineca Natural Resource Region, where most of the glyphosate application occurs, deciduous components accounted for 15–21% of the stand density on sites that were previously treated with glyphosate. Data also show that in the B.C. Interior, mixed deciduous stands have been increasing over time as a result of forest management activities.

A summary of the many studies on the impact of glyphosate on forest soils, water, non-target plant communities, and wildlife is presented. While impacts can vary with site characteristics, research has shown that the risk of glyphosate and its metabolites on the environment is minimal when the herbicide is applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes to these communities are related to changes in vegetation structure and are transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects of glyphosate on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. Recent research has found low but unexpected levels of glyphosate residue in plants 1 year following treatment, which may have implications for wildlife forage quality, plant physiology, and

traditional food and medicine plant harvesting. While residue levels were non-toxic to humans and wildlife, little is known about their persistence and their effect on forage quality and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

Glyphosate remains an important tool for establishing conifer or conifer–deciduous mixed stands and ensuring future timber supply. Glyphosate bans in other jurisdictions in Canada have resulted in significant struggles to meet silvicultural objectives on the land base, which highlights glyphosate's important role in maintaining conifer productivity. Forest management in B.C. seeks to balance all values ascribed to the forest, with the overarching objective of establishing and maintaining healthy and diverse forests. While more research on the identified knowledge gaps is recommended, glyphosate needs to be considered in the context of these values and objectives, and with perspective regarding the amount of area treated, the apparent transient effects on the site's ecology, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels.

1 INTRODUCTION

Public pressure to reduce the use of glyphosate has been increasing in British Columbia (B.C.) and other jurisdictions. In response, the Office of the Chief Forester for the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) contracted FPInnovations to undertake a review of current peer-reviewed forest science and best practices on glyphosate use in B.C. forestry. Input from stakeholders was also solicited. The forestry use of glyphosate in relation to the multiple values pertinent to forest management in B.C. was considered. The report will inform future policy development and research needs, with the main objective to promote the establishment of healthy and diverse forests.

Successful regeneration of forests after timber harvesting often requires control of competing vegetation, which may cause mortality or reduced growth of established seedlings. Several vegetation management alternatives exist for this purpose, including chemical (e.g., glyphosate, triclopyr) and non-chemical (e.g., manual cutting, girdling, sheep grazing) methods.

Glyphosate-based herbicides are the most widely used in the world, largely due to their effectiveness, their safety for non-target species and the environment, and the development of glyphosate-tolerant agricultural crops. Several factors support the use of this herbicide in forestry applications in B.C.:

- ability to translocate within treated plants and control resprouting of perennial weeds;
- generally favourable environmental profile, including binding in soils and rapid biodegradation in most soils, water, and sediments;
- specific mechanism of action, inhibiting an enzyme found in plants;
- low toxicity to animals; and
- minimal impact on forest ecosystems (Rolando et al., 2017).

This report focuses on glyphosate application for silviculture as a vegetation management tool in re-establishing forest stands post-harvest. The use of glyphosate for agriculture, transmission or transportation corridors, or other industrial uses is outside the scope of this report. The effects of glyphosate on human health and the environment have been extensively reviewed by regulatory agencies (Appendix 1), including by Health Canada's Pest Management Regulatory Agency as recently as 2017 and again in 2019. These findings are summarized in Appendix 1.

2 USE OF GLYPHOSATE IN BRITISH COLUMBIA FORESTS

2.1 Regulatory Framework

2.1.1 Free Growing

In B.C., timber harvesting in public forests is regulated such that any harvested area must be reforested to an acceptable standard of free growing. The *Forest Range and Practices Act* (sec 1) defines "free growing" as "a stand of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees". A free-growing stand is expected to contribute to landscape objectives and to a sustainable long-term fibre supply.

The Forest Planning and Practices Regulation (FPPR) (sec 44) addresses obligations to produce a free-growing stand that meets applicable stocking standards approved in a Forest Stewardship Plan (FSP) by specified dates. Stocking standards are regulatory tools that ensure that the re-establishment of a forest stand post-harvest is aligned to large-scale objectives for the land base as set out in FSPs. Stocking standards specify regeneration requirements such as suitable tree species for the site, stand density, spacing, free-growing height, and ratio of crop tree height to surrounding competing vegetation.

Sec 46.11 of the FPPR indicates that these silvicultural obligations must be fulfilled on each hectare within the net area to be reforested, unless otherwise specified in an FSP. Mappable areas that do not meet stocking standards should not exceed 2 ha or 5% of the Standards Unit area. Under the FPPR (sec 97.1), an obligation holder may be relieved of the obligation to meet stocking standards if they can prove that obligations have been met to the extent that is practicable.

Sec 26 (5) of the FPPR also provides a mechanism for developing stocking standards in an FSP that are not consistent with current timber supply assumptions. The review test for sec 26 (5) requires the delegated decision maker to be satisfied that the regeneration date and stocking standards are reasonable, having regard for future timber supply and the set values ascribed to forest land.

Free-growing surveys are the tool that forest managers use to measure whether a stand meets free-growing obligations. Survey methods, including quantification of shrub and broadleaf competition, are described in the Silviculture Surveys Procedures Manual.

Stocking standards and related guidance have evolved since the 1990s and continue to evolve to incorporate current understanding of resource issues (e.g., broadleaf species) and their impact on timber supply and other forest values. A summary of these developments is described in Appendix 2.

2.1.2 Herbicides

Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada to ensure that pesticides pose minimal risk to human health and the environment. Under authority of the *Pest Control Products Act*, Health Canada:

- registers pesticides after a stringent, science-based evaluation that ensures any risks are acceptable;
- re-evaluates the pesticides currently on the market on a 15-year cycle to ensure the products meet current scientific standards; and
- promotes sustainable pest management.

The latest PMRA re-evaluations of glyphosate safety were conducted in 2017 and then again shortly after in 2019 (PMRA 2017, 2019). Following the release of the re-approval decision in 2017, Health Canada received eight notices of objection that questioned the validity of the re-evaluation after revelations that several scientific publications may not have followed due scientific process in what came to be called the Monsanto Papers. After a scientific review of these claims and the publications in question, the PMRA issued a statement in January 2019 indicating that the objections did not cast doubt on the original 2017 decision, and that glyphosate remains approved for use in Canada (PMRA, 2019).

The *Integrated Pest Management Act* and Regulation (IPMR) sets out the requirements for the use and sale of pesticides in B.C. The B.C. Ministry of the Environment and Climate Change Strategy promotes Integrated Pest Management and environmental stewardship and ensures compliance with the *Integrated Pest Management Act* and Regulation. Large-scale pesticide programs (i.e., > 20 hectares per year of treatment area) that require Integrated Pest Management must have a confirmed Pest Management Plan (PMP). These plans document how the standards set in the IPMR will be implemented regarding environmental protection, notification, and herbicide handling and application, as well as alternatives to using herbicides. The content of PMPs is detailed in Appendix 3.

Integrated Pest Management is a process for managing pest populations. In a forestry context where competing vegetation is considered as a pest or weed, the following integrated vegetation management elements would apply:

- planning and managing ecosystems to prevent organisms from becoming weeds;
- identifying weed problems and potential weed problems;
- monitoring weed populations and weed complexes;
- using injury thresholds, levels at which pest numbers are high enough to cause unacceptable injury or damage, in making treatment decisions;
- selecting pest treatment methods based on:
    - consideration of practical alternatives to herbicide use,
    - protection of human health and the environment; and

- evaluating the effectiveness of weed management treatments.

Herbicides are rarely the only integrated vegetation management method used and are generally used in conjunction with other methods. Examples of best practices for implementing integrated vegetation management are included in Appendix 3.

2.2 Why is Glyphosate Used?

Managing competing vegetation is an essential part of reforestation efforts after forest harvesting. In B.C., vegetation management focuses on highly aggressive herbaceous complexes such as fireweed or bluejoint grass, and competitive deciduous trees such as red alder and trembling aspen. Targeted vegetation control is used in silviculture for two main reasons:

- to maintain plantation survival; and
- to meet free-growing obligations that ensure stand productivity and sustainable future timber supply.

Glyphosate is one of many chemical and non-chemical vegetation management tools available to forest managers (see Appendix 3 for other vegetation management alternatives). It may be applied aerially or with ground-based methods such as backpack sprayer, hack and squirt, cut stump, and vehicle-mounted sprayer. In recent years, backpack spraying has been the most common ground-based treatment used, while broadcast boom spraying with helicopters is the only aerial method used.

The primary benefit of using glyphosate is its effectiveness in controlling competing vegetation. Because it is easily translocated within the target plant, killing it outright, it can reduce the brush hazard for multiple years after a single application, as opposed to manual methods, which do not kill root systems and may result in re-sprouting of perennial weeds or stimulation of suckering by trembling aspen. Manual vegetation control treatments typically provide only short-term relief from competing vegetation, with control often lasting only for the balance of the growing season in which the treatment was applied (Miller 1985; Hart and Comeau 1992; Comeau et al., 1999, 2000). Several studies have found that a single manual treatment may be ineffective for sufficiently controlling cover to benefit seedling growth for more than a few years (Ehrentraut and Brantner 1990; Harper et al., 1997; 1998; Whitehead and Harper 1998; Comeau et al., 1999, 2000; Simard 2001; Heineman et al., 2005). The main manual methods used to control competing vegetation are brush saws, manual cutting, and power saws. Other methods such as girdling, sheep grazing, and stem bending using hockey sticks are used on a smaller scale due to their logistical difficulties and high cost.

The need for multiple treatments when relying on manual treatments, the higher cost associated with them, the increased safety risk to manual brushing workers, and the limited availability of brushing crews have helped make glyphosate a popular vegetation control alternative. No single vegetation control method suits all sites, however. Logistical, environmental, and safety concerns affect the choice of vegetation management. BC Timber Sales (BCTS) and licensees with reforestation obligations document when and how herbicides and other vegetation control methods are used in their Pest Management Plans (see Appendix 3).

Depending on the developmental stage of a plantation and its brush complex, glyphosate may be used to clear a planting site of pre-established brush, to reduce seedling competition in order to ensure plantation survival, or to meet free-growing requirements that ensure long-term productivity and timber supply, particularly where management is focused on specific timber species and outcomes.

2.2.1 Site Preparation

Glyphosate is sometimes used to prepare a site for planting where highly competitive vegetation complexes have become established prior to planting. Vegetation control before planting is preferred where it is expected that vegetation will impact plantable spots, target planting density, and plantation survival and growth. The average annual area of sites prepared with glyphosate between 2008 and 2018 was 152 hectares per year, which was less than 2% of the total area treated with herbicides, and mostly ground-based application was used.

2.2.2 Plantation Survival

Plantations on sites with aggressive competing vegetation complexes can fail within a year without effective vegetation management. In these cases, interventions are often needed to avoid excessive seedling mortality and plantation failure (Comeau et al., 1999; Biring et al., 2003; Comeau and Harper, 2009). This application of glyphosate is particularly important with herbaceous vegetation complexes for which mechanical cutting is not effective, such as bluejoint reed grass. Bluejoint reed grass is a serious competitor in northeastern B.C., where it often colonizes sites after harvest and forms thick colonies that can prevent establishment of shrub and tree species for upwards of 25 years if left uncontrolled (Dunbar et al., 2011). Glyphosate application on these sites can suppress the growth of competitive vegetation, thereby enabling tree seedlings to become established.

2.2.3 Crop Tree Productivity

To meet silvicultural objectives for the site, vegetation management may be required to release established crop trees that are overtopped by competing vegetation and at risk of becoming suppressed. A single application of glyphosate during the first few years after planting in high-brush sites has been shown to effectively improve conifer growth 9–20 years later in a wide range of plant communities in various ecosystems in B.C. (Harper et al., 1997; Whitehead and Harper 1998; Biring et al., 1999; Biring and Hays-Byl 2000; Simard 2001; Harper et al., 2005; Boateng et al., 2006; Macadam and Kabzems 2006). There is substantial variation in the magnitude of reported growth gains because they are dependent on the type, intensity, and duration of vegetation competition; in certain cases, the effects have been found to be significant but can also be short-term (Comeau et al., 1999; Heineman et al., 2005; Comeau and Harper, 2009).

2.2.4 Invasive Species

While the focus of this report is on the use of glyphosate in B.C. silviculture, the herbicide may also be used in forests to control the spread of noxious and invasive weeds across the province. The *Forest Range and Practices Act* (sec 47) indicates that a person who is conducting a forest or range practice must use measures to prevent the introduction or spread of prescribed species of

invasive plants, as listed in the Invasive Plants Regulation. The B.C. *Weed Control Act* requires all land occupiers to control the spread of noxious weeds on their land or premises.

British Columbia has four multi-agency Pest Management Plans (PMPs) for invasive plant management, which together cover the entire province and all invasive plant treatments in B.C. Ministry of Transportation and Infrastructure, FLNRORD, and BC Parks jurisdictions. In 2018, the total area treated with herbicides for control of invasive plant species in these jurisdictions was 1593 ha, 8% of which was treated with glyphosate.[1] However, glyphosate comprised as much as 80% of the total herbicide use in the South Coast PMP program due partly to the focus on Japanese knotweed control. For many noxious weeds, such as knotweeds and some invasive grasses, manual treatments are not effective. Ten-year results from a B.C. study that compared knotweed control methods indicated that manual treatments are ineffective and can actually cause the plants to spread further (C. Chadburn, personal communication, 2019).

Glyphosate products are also used in areas where a short half-life or immobility in the soil is required, where soils, gravels, or other materials may be moved in the future, or near private gardens or other sensitive features. Glyphosate is an important treatment for riparian zones where a significant portion of invasive plants/noxious weeds occur. It is the only herbicide that allows the regulated 10-m pesticide-free zone to be reduced to 1 m when using selective application methods.

2.3 How is Glyphosate Used?

2.3.1 Area Treated

Data from the RESULTS database show that approximately 11,000 ha of Crown land were treated with glyphosate for silvicultural purposes in 2018,[2] with 86% sprayed aerially and 14% sprayed using ground-based methods (Figure 1) (see Appendix 3 for descriptions of aerial, ground-based, and alternative treatment methods). The area sprayed has declined from an average of 13,802 ha from 2013 to 2018 and higher historical levels. The area sprayed in 2018 was 0.044% of the 25 million hectares available for harvesting in B.C. and 0.44% of the tenured area on Crown land that has an outstanding reforestation obligation.

The proportion of area harvested that has had any kind of vegetation control treatment decreased from 18 to 14% between 2008 and 2018. Over that time, herbicides, primarily glyphosate, were applied to half the treated area, while the rest of the area was treated using non-chemical methods (Figure 2), primarily clearing with brush saws (Figure 3). The use of brushing declined due partly to the increase in mountain pine beetle (MPB) salvage. As MPB salvage winds down, BCTS and Interior licensees are moving their harvesting operations to wetter sites with potentially greater brush hazards, which might result in an increase in the need for vegetation control.

---

[1] Compared to 11,000 ha treated with glyphosate in B.C. for silviculture.

[2] Includes aerial and ground-based brushing and site preparation treatments but excludes basal spray and stem bark spray silviculture methods, which do not apply to glyphosate-based herbicides. It may include some triclopyr application that was reported as backpack treatment method. Private land is not included.

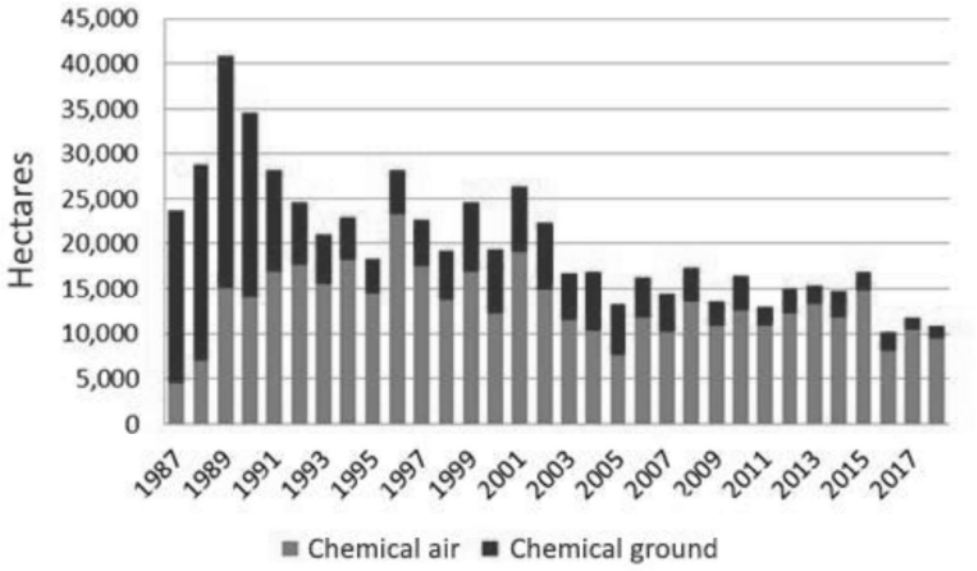


Figure 1. Area sprayed with glyphosate for silviculture in British Columbia.

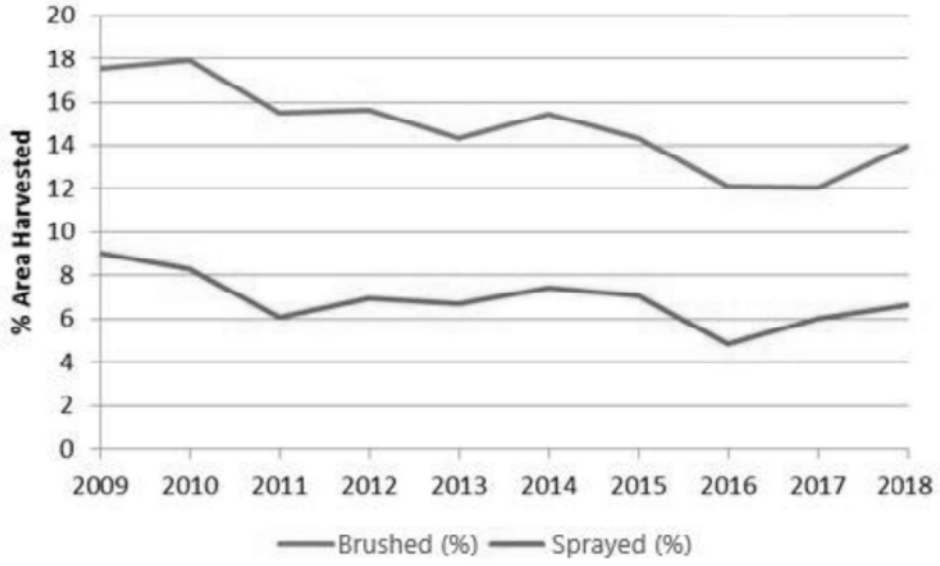


Figure 2. The percentage of harvested area that was brushed using alternative methods and sprayed with glyphosate.

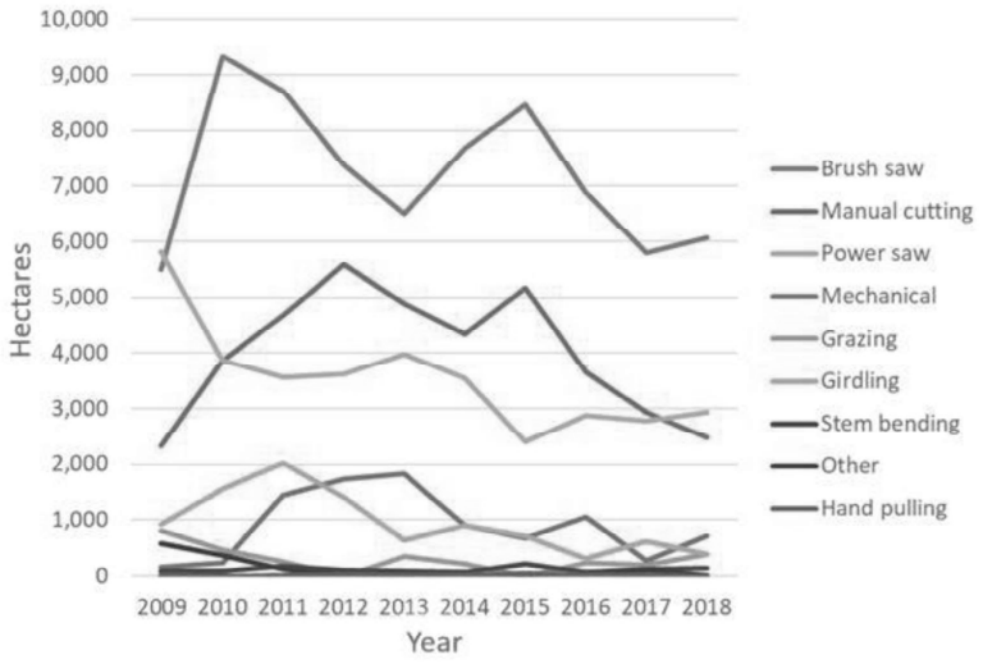


Figure 3. Area brushed using non-chemical methods.

Most of the glyphosate spraying was conducted in the Omineca Natural Resource Region (73% of all area treated), followed by the Northeast Region (11%) (Table 1). The Prince George Timber Supply Area comprised 68% of the total provincial area sprayed with glyphosate in 2018. Aerial applications made up 96% of the spray programs in those regions. Small aerial programs were also conducted in the Thompson-Okanagan and South Coast Regions. Small ground-based programs were conducted in all regions, with the largest occurring in the South Coast Region. The proportions of area harvested that were sprayed with glyphosate ranged from 11 to 15% in the Northeast, South Coast, and Omineca Regions, while less than 3% of the harvested area in the remaining regions was sprayed (Table 1).

Table 1. Area sprayed with glyphosate, by Natural Resource Region, in 2018

Natural Resource Region	Area harvested (ha)	Area treated with herbicide (ha)			% of harvest area
		Aerial	Ground-based	Total	
Omineca	52,795	7,673	301	7,974	15.1
Northeast	11,574	1,179	60	1,239	10.7
Thompson-Okanagan	25,635	565	18	583	2.3
South Coast	4,060	35	520	555	13.7
Kootenay-Boundary	14,333	0	234	234	1.6
West Coast	10,620	0	175	175	1.6
Skeena	16,346	0	169	169	1.0
Cariboo	28,418	0	39	39	0.1
B.C. total	**163,781**	**9,452**	**1,516**	**10,968**	**6.7**

The biogeoclimatic (BEC) zones (Meidinger and Pojar 1991) in which most of the glyphosate application was conducted were the Sub-Boreal Spruce (SBS) (76%) and Boreal White and Black Spruce (BWBS) (9%) zones (Table 2). Four subzones of the SBS accounted for 68% of the total provincial area that was sprayed (Figure 4). The drier SBS subzones (dry warm [dw] and moist cool [mk]) are generally dominated by aspen, while the wetter subzones (wet cool [wk] and very wet cool [vk]) are dominated by herbaceous vegetation.

Table 2. Area sprayed with herbicide, by biogeoclimatic zone, in 2018

BEC zone	Area treated with herbicide (ha)		
	Aerial	Ground-based	Total
Sub-Boreal Spruce (SBS)	7,865	416	8,281
Boreal White and Black Spruce (BWBS)	941	60	1,001
Coastal Western Hemlock (CWH)	27	662	689
Engelmann Spruce – Subalpine Fir (ESSF)	414	135	549
Interior Cedar – Hemlock (ICH)	195	192	387
Interior Douglas-fir (IDF)	0	52	52
Mountain Hemlock (MH)	8	0	8
B.C. total	**9,450**	**1,517**	**10,967**

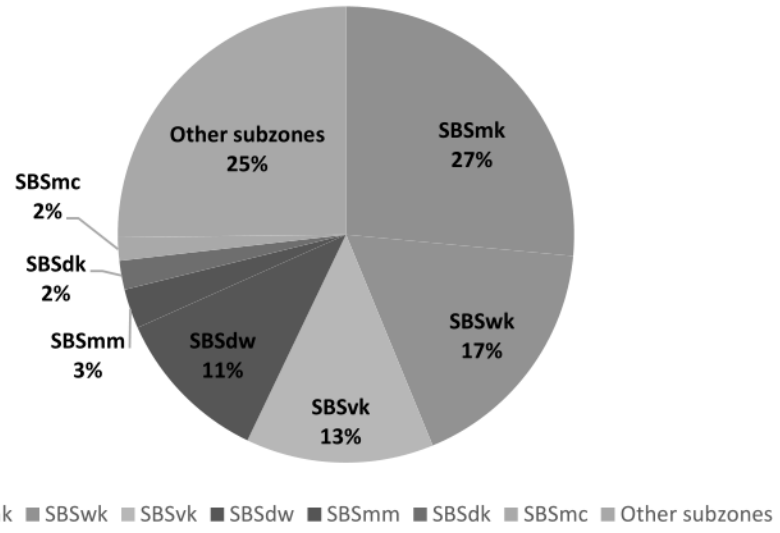


Figure 4. Herbicide use by biogeoclimatic subzone. (SBS: Sub-Boreal Spruce, mk: moist cook, wk: wet cool, vk: very wet cool, dw: dry warm, mm: moist mild, dk: dry cool)

2.3.2 Glyphosate Use at the Stand Level

Glyphosate is generally used in a targeted portion of the total reforestation area, as opposed to covering entire cutovers. In more than two-thirds of all cutovers treated with herbicide since

1998, the treatment area was less than 80% of the total net area to be reforested.[3] The distribution of net area to be reforested that was treated with herbicide is illustrated in Figure 5.

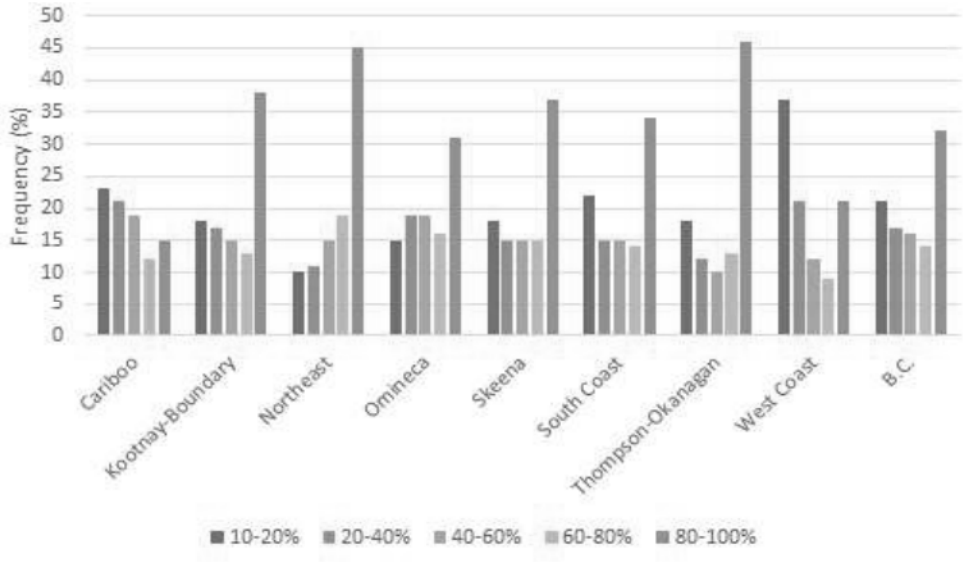


Figure 5. Distribution of the percentage of area treated with glyphosate within the net area to be reforested in a block, since 1998. Data is for one-time treatments only.

In contrast with agriculture and other common land uses where areas are sprayed repeatedly, in forestry, glyphosate is generally applied once or twice in a rotation. Since 1998, 47% of blocks that had ground-based herbicide treatments and 65% that had aerial treatments were treated once (Table 3). The percentage of blocks treated more than twice was 32% for ground-based and 11% for aerial treatments. The Coast regions had a higher proportion of retreatments than other regions. BC Timber Sales and licensees indicated that efforts are made to minimize areas sprayed to reduce costs and address public pressure.

Table 3. Number of herbicide treatments on a given area, since 1998

Natural Resource Region	Ground-based treatment			Aerial treatment		
	Number of treatments			Number of treatments		
	1	2	> 2	1	2	> 2
Cariboo	74%	20%	6%	83%	16%	1%
Kootenay-Boundary	44%	42%	14%	100%	0%	0%
Northeast	64%	25%	12%	53%	30%	17%
Omineca	89%	10%	1%	68%	24%	8%
Skeena	79%	11%	10%	70%	15%	15%
South Coast	41%	29%	30%	79%	21%	0%
Thompson-Okanagan	75%	17%	8%	45%	33%	22%
West Coast	24%	19%	58%	63%	25%	11%
B.C. total	**47%**	**21%**	**32%**	**65%**	**25%**	**11%**

[3] This analysis included blocks that were treated with herbicide only once.

Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species. Commonly targeted vegetation complexes in the SBS, where most of the glyphosate application occurs, are trembling aspen, mixed shrub, fireweed, and wet alder. The BWBS zone is dominated by aspen/poplar and reed grass complexes (Comeau et al., 1996).

Target species are indicated on brushing prescriptions that are developed from operational surveys. A licensee in the Prince George region indicated that 53% of the 2018 aerial spray area targeted aspen, while 47% targeted herbaceous/shrub competition. Aggregated data on which complexes are targeted the most by glyphosate application are currently lacking. More work is required to understand how glyphosate use is distributed among particular vegetation complexes or species to understand how and why glyphosate is used, and what the impact of not using it would be.

2.4 Treatment Costs

Treatment costs vary considerably depending on location, access, treatment intensity, availability of crews and equipment and logistics. BC Timber Sales and licensees reported that manual treatments (Can$700–$1200/ha) are more than twice the cost of glyphosate treatments (Can$300–$500/ha) and require at least two treatments. The cost of achieving free growing on a site that needs vegetation control ranges from Can$900 to Can$2100/ha more when using manual treatments. BC Timber Sales provided an example of treatment costs to attain free growing with and without glyphosate in the Prince George Region (Table 4). Assuming this example is representative and applying an average cost difference of $1400/ha to the 11,000-ha area that was sprayed in 2018, the cost of not using glyphosate for silviculture is estimated at Can$15.4 million per year.

Table 4. Cost of achieving free-growing, Prince George Region (Source: BC Timber Sales)

Activity	Vegetation management with glyphosate	Vegetation management with motor-manual treatments
Plant regular stock ($/ha)	$624	
Plant large stock ($/ha)		$900
Glyphosate application ($/ha)	$354	
Manual brush ($/ha) × 2		$1,460
Surveys	$70	$90
Cost to free-growing	**$1,048**	**$2,450**

Although costs are an important consideration, safety, access, crew availability, treatment windows, and various operational factors also affect the selection of treatment options discussed in Appendix 3.

3 IMPACT OF GLYPHOSATE USE ON NON-TIMBER VALUES

3.1 Biodiversity

The FPPR states that the objective set by the B.C. government for wildlife and biodiversity at the landscape level is, without unduly reducing the timber supply from British Columbia's forests and to the extent practicable, to design areas on which timber harvesting is to be carried out that resemble, both spatially and temporally, the patterns of natural disturbance that occur within the landscape.

3.1.1 Broadleaf Tree Species

Mixedwood forests provide various ecological, social, and non-timber values; have significant value in shaping forest ecology, stand structure, and function; and exert a strong influence on forest diversity and resilience (Harper and Roach 2014). One of the primary concerns the public has expressed regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broad-leaves are being eliminated from the landscape. These claims, however, are not supported by analyses of the amount of deciduous components remaining at free-growing in blocks that have been treated with glyphosate, or the increase in mixed deciduous stands over time as a result of forest management (BC MFLNRO 2008).

3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide treatment

On sites where aspen exists pre-harvest, it regenerates aggressively from suckering after a stand-replacing event such as fire or harvesting (Frey et al., 2003). This is particularly true in the boreal and sub-boreal mixedwoods that comprise large portions of central and northeastern B.C., where research has shown that in order to establish a conifer crop, vegetation management is often required to counter aspen suckering following harvesting[4] (Wood and von Althen, 1993; Cole et al., 2003; Pitt and Bell, 2005; Boateng et al., 2006).

On these sites, deciduous mixes often develop, even after conventional vegetation management treatments (including glyphosate) are used because a percentage of broad-leaves in a treated stratum may survive or produce suckers after treatment (Perala, 1985, Navratil et al., 1991; Bell and Newmaster, 2002; Pitt et al., 2004a, 2004b; Pitt and Bell, 2005; Kabzem and Harper, 2015). Medium- and long-term studies on the effect of a one-time glyphosate application on stand composition in boreal sites have recorded 15–21% deciduous stand components 5–30 years after treatment (Pitt et al., 2004a, 2004b; Pitt and Bell, 2005; Kabzem and Harper, 2015).

While those studies focused on deciduous composition within herbicide-treated areas, it is important to note that glyphosate is not generally applied to entire harvest units (see Section 2.3.2), and that the total elimination of competitive vegetation is not a silvicultural objective of conifer-release programs (Bell and Newmaster, 2002). In B.C., vegetation management

[4] Suckering from a single aspen parent tree can cover 500 m^2 at densities of up to 250,000 sph (Navratil et al. 1991)

treatments, including glyphosate application, are carried out only in the portions of a harvest unit where they are deemed necessary for conifer survival or to meet free-growing stocking standards in each standard unit as per sec 46.11 of the FPPR.

3.1.1.2 RESULTS analyses

A 2008 Forest and Range Evaluation Program review of tree species composition pre- and post-harvest in B.C. found that the amount of deciduous mixed stands at free growing increased from 2811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods (BC MFLNRO 2008). Similarly, in the Southern Interior Forest Region, deciduous mixed stands increased from 1202 ha before harvest to 37,268 ha at free growing, a 3000% increase.

An up-to-date RESULTS query of stand composition for all stands declared free growing following herbicide treatment (aerial and ground-based) was prepared by FLNRORD. The inventory labels from free-growing surveys were examined for openings that were sprayed > 5 years after harvest and surveyed 2–25 years after spraying. The data showed that province-wide, the average number of deciduous stems per hectare (sph) in a survey polygon after aerial and ground-based treatment was 504 and 449, respectively (Table 5). This corresponds to 16% and 15% broadleaf components (by stem density).

In the Omineca and Northeast Regions, where most herbicide treatments are conducted, the average number of deciduous stems per hectare at free growing after aerial herbicide treatments was 445 and 864, respectively, or 15% and 27% of the total stand species composition (Table 5). Similarly, in the SBS zone (the BEC zone where most herbicide application occurs), there was an average of 455 and 577 sph of deciduous at free growing for aerially and ground-based treated openings, respectively. The averages in Table 5 do not show the variation in sample sizes and stocking that can occur from year to year or among openings.

In general, for most regions, ground-based application resulted in a slightly higher number and percentage of deciduous stems at free growing compared with aerial application. Backpack-type application can be more selective compared to broadcast aerial treatments, and leave untreated stems between crop trees, which is less likely with aerial broadcast treatment.

Table 5. Deciduous stocking at free growing following aerial or ground-based herbicide treatments

Natural Resource Region	Deciduous components, post-aerial treatments		Deciduous components, post-ground-based treatments	
	Average deciduous density (sph)[a]	Deciduous component (%)	Average deciduous density (sph)	Deciduous component (%)
Omineca	445	14.7	699	21.2
Northeast	864	26.5	828	27.6
Cariboo	436	9.6	583	12.6
South Coast	94	4.8	120	7.2
Kootenay-Boundary	130	4.1	185	5.2
Skeena	237	8.9	230	7.7
Thompson-Okanagan	–	–	355	8.9
West Coast	–	–	449	14.6

B.C. Average	**504**	**16.4**	**449**	**14.6**

– Missing values indicate no survey data for the region.

[a] sph: stems per hectare

The results of the analysis suggest that deciduous stocking does recover after glyphosate spraying and may in fact be increasing over time with forest management activities. Deciduous components are important for many forest management objectives (e.g., wildlife habitat, wildfire, carbon), yet they also affect timber supply objectives. Research shows that increases in deciduous volume in a stand negatively affect conifer volume (Kabzems et al., 2007; Harper and Roach, 2014; Harper, 2015) (see Section 3.3).

3.1.2 Non-Target Plant Communities

3.1.2.1 Diversity of plant communities

A review of 12 studies found that species richness and diversity of non-target vascular plants was not negatively affected when measured 5–12 years after glyphosate application (Sullivan and Sullivan 2003). Studies report that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as 1–2 years after treatment (Freedman et al., 1993; Bell and Newmaster, 1998; Sullivan et al., 1998; Lautenschlager and Sullivan, 2002; Hawkins et al., 2013; Comeau and Fraser, 2018). In many cases, herbaceous vegetation abundance, diversity, and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank (Sullivan and Sullivan, 2003; Kabzems and Harper, 2015).

While broadcast aerial spraying of glyphosate is sometimes seen as a blunt vegetation management tool, studies have found that it does not target all vegetation equally. One study found that on sites with a vertical vegetation structure (comprised of aspen, shrubs, and forbs), most of the spray was deposited in the aspen canopy (68% of the nominal application rate), while shrubs and herbs captured approximately 25% and 12% of the nominal application rate, respectively, which may further help explain their quick recovery (Thompson et al., 1997).

Only two of the 12 studies Sullivan and Sullivan (2003) analyzed showed an overall reduction in species richness of shrubs after glyphosate application (Sullivan et al., 1998; Santillo et al., 1989). Santillo et al. (1989) found that species richness decreased by 50% and 30% for shrubs and herbs, respectively, 1 year after treatment and continued to be lower in the treatment units after 3 years. However, the control sites in this study were at a different successional stage than the glyphosate treatment units (Santillo et al., 1989). Sullivan et al. (1988) likewise observed a reduction in shrub species richness 5 years after treatment.

Other brushing alternatives such as manual brushing may have effects similar to glyphosate application on plant community composition. Lindgren and Sullivan (2001) compared manual cutting of stump sprouts and cut-stump application of glyphosate, and found no difference in species richness, diversity, structural diversity, or turnover of herbaceous, shrub, and tree communities. In a similar study, Bell and Newmaster (2002) showed that herbicides had a relatively greater initial effect on plant community composition compared to two mechanical vegetation control treatments, but that woody, herb, and grass layers recovered to pre-treatment levels within 5 years.

3.1.2.1 Persistence of glyphosate/aminomethylphosphonic acid in plant tissue

Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions (Gomes et al., 2014) due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least 1 year (Wood 2019). Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality; however, some translocation into shoots and fruit was observed in select plants (Wood 2019). While residue levels were non-toxic to humans and wildlife, little is known about the persistence timelines of residues, their effect on forage quality, and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

3.1.3 Aquatic Organisms

Amphibian populations are declining around the world (Houlahan et al., 2000), and chemical contaminants released into aquatic environments have been listed as the second most important threat to amphibians after habitat loss (Edge et al., 2011). Laboratory and mesocosm studies have shown direct effects of chronic exposures to glyphosate-based herbicides, particularly those containing the polyethoxylated tallow amine surfactant, on fish, amphibians, invertebrates, and other components of aquatic ecosystems (e.g., Folmar et al., 1979; Wan et al., 1989; Edglnton et al., 2004; Howe et al., 2004; Edge et al., 2014a, Lanctot et al., 2014, Navarro-Martin et al., 2014). However, studies have not been able to replicate these toxicity effects in the field under typical application rates and conditions.

Numerous whole-ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development (Edge et al., 2012, 2014b; Lanctot et al., 2013), expression of genes related to larval development (Lanctot et al., 2013), or juvenile amphibian survival (Edge et al., 2011, 2013). This is likely due to the short (but environmentally realistic and relevant) exposure duration (generally less than 96 hours) and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands (Edge et al., 2012, 2014b; Baker et al., 2016).

A watershed-level study in coastal B.C. found temporary stress effects and minor mortality (2.6%) in caged coho salmon smolt in an experimentally over-sprayed tributary and the main stream below the sprayed area immediately after glyphosate application. No acute mortality or changes in overwinter mortality, growth rate, or use of the tributary were observed for resident coho (Feng et al., 1990; Legris and Couture, 1991; Reynolds et al., 1993). Similarly, no effects on growth, behaviour, or histopathology of gills and livers of resident rainbow trout were found after a two-month exposure to herbicide in a separate tank experiment (Morgan and Kiceniuk, 1992).

Studies have found temporary effects on aquatic ecosystems due to changes in the vegetation after direct glyphosate application to water bodies. One study showed that glyphosate application caused a decrease in total macrophyte cover and species richness, an increase in species evenness, and a reduction in community similarity when compared to unexposed wetland sites (Baker et al., 2016). One year after herbicide applications, the wetland vegetation began to recover. Studies on aquatic macroinvertebrates have found similar results: one study found that 10% of the benthic macroinvertebrate taxa were eliminated after herbicide application but recovered in 1 year (Baker et al., 2014). Similarly, Linz (1999) reported no

negative effects and even increased arthropod abundance 1 year after direct overspray of a wetland. Rzymski et al. (2013) found no difference in taxa diversity but slight decreases in abundance of some taxa, which where hypothesized to be short term.

While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations require the maintenance of pesticide-free zones around water features, dry streams, and classified wetlands (IPMR, sec. 73 (1)), which further reduces the risk of negative effects on aquatic ecosystems. Various Canadian studies on surface water glyphosate residue have found no detectable glyphosate or AMPA concentrations (i.e., < 5000 ug a.i./L) post-treatment when using buffers of 100 m for aerial and 10–60m for ground applications (Eremko, 1986; Wan, 1986; Gluns, 1989; Adams et al., 2007). Canadian Water Quality Guidelines for the protection of aquatic wildlife stipulate maximum short-term and long-term glyphosate exposures of 27,000 ug a.i./L and 800 ug a.i./L, respectively[5] (CCME, 2012).

3.1.4 Wildlife

3.1.4.1 Toxicity

Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals, and birds have found risk quotients below the level of concern when typical field application rates were used (Giesy et al., 2000; Durkin et al., 2003; PMRA, 2015). Some uncertainty remains regarding the effects of long-term chronic exposure to low levels of glyphosate on wildlife due to glyphosate persistence in forage. While recorded residue levels were non-toxic to mammals, the effects of chronic sub-lethal exposure to mammals are not yet well-understood and require more research (Mesnage et al., 2015; Kissane and Sheppard, 2017; Wood, 2019).

Effects on terrestrial wildlife communities, like in aquatic ecosystems, are linked primarily to the changes in vegetation cover and forage quality. As such, species responses are highly variable and reflect individual habitat preferences. Studies on wildlife responses to habitat alteration due to glyphosate application have shown no effect, short-term negative effects, and positive effects on different wildlife species (Guynn et al., 2004). All in all, studies suggest that species richness and diversity of small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes are transient and related to changes in vegetation structure (Sullivan and Sullivan 2003).

3.1.4.1 Forage quality and quantity

Moose populations have been declining in several regions of B.C., and forage availability and quality has been flagged as a potential contributing cause (Kuzyk et al., 2018). Glyphosate treatment has been found to reduce wildlife forage availability in the short term (as compared to no vegetation control treatment), which results in reduced moose use of glyphosate-treated areas for the first few years after treatment (Hjeljord and Gronvold 1988; Connor and McMillan 1990; Lautesnschlager, 1993; Eschholz et al., 1996; Lautenschlager et al., 1999). The long-term impact of glyphosate use on habitat selection by moose is not well understood, however. Biring

[5] Values are based on median lethal dose (LC_{50}) data for 19 aquatic species.

et al. (1999) reported reduced forage abundance and use 12 years after glyphosate application in a BWBS site. However, Newton reported a 46% decrease in forage abundance the year following glyphosate application but a 660% increase at year 8 compared to the control (Newton et al., 1989), and some studies have shown that 7–11 years post-treatment, moose seem to favour treated areas over controls (Eschholz et al., 1996; Raymond et al., 1996). These impacts must also be considered in relation to the area that is treated annually and its distribution over the landscape (Lautenschlager and Sullivan 2002).

The effects of glyphosate's chelating properties on forage quality and nutrient availability are poorly understood. The properties allow glyphosate to bind macronutrients and micronutrients (in particular iron, manganese, zinc, copper, and nickel), which can impact uptake and availability in plants treated with glyphosate (Mertens et al., 2018). These micronutrients are particularly important to ungulates such as moose, whose sensitivities to mineral imbalances (in particular copper) have been implicated in moose population declines in Alaska, Sweden, and Minnesota (Flynn et al., 1977; Frank et al., 1994; O'Hara et al., 2001; Custer et al., 2004).

Studies on nutrient uptake by surviving plants in agricultural settings after glyphosate application have provided contradictory accounts (Gomes et al., 2014). In some cases, a reduced uptake of micronutrients by plants has been found (Eker et al., 2006; Cakmak et al., 2009; Tesfamariam et al., 2009), while in others (Duke et al., 2012, 2018), no effect on micronutrient content was found. More research on whether glyphosate application leads to reduced micronutrient content specifically in wildlife forage is required, and whether this is implicated in the moose population declines in B.C.

3.2 Soil and Water Quality

3.2.1 Glyphosate/aminomethylphosphonic acid fate in soils

After application, glyphosate is largely immobilized in the soil due to its strong sorption characteristics, which allow it to bind with soil particles and organic materials. Once glyphosate reaches the soil, the main pathway for its dissipation in soil is microbial degradation, as many species of soil microorganisms can use glyphosate as their soil carbon source (Durkin, 2003). One of the main compounds released during the microbial breakdown process, AMPA, is likewise adsorbed to soils and biodegraded, yet it is considered to be a mild phytotoxin (Reddy et al., 2004; Gomes et al., 2014) with relatively unknown long-term effects on soil organisms and plants.

Sorption and degradation processes are highly dependent on microbial activity and soil composition (Székács and Darvas, 2012). The rate of sorption and degradation of both glyphosate and AMPA vary greatly in agricultural applications, with half-lives ranging from a few days to several months, and even up to 1 year (Székács and Darvas, 2012). While it has been argued that the short growing season in northern climates may restrict degradation, North American studies in forest applications have found that the time for 50% dissipation (DT_{50}) in litter and soil is 8–19 days and 5–40 days, respectively (Newton et al., 1984, 1994; Feng and Thompson, 1990; Thompson et al., 2000; Hagner et al., 2019).

3.2.2 Soil microorganisms

Soil organisms play a crucial role in nutrient cycling and maintaining ecosystem productivity. Research on the effect of glyphosate on microorganisms in laboratory studies has been contradictory. Those studies have found exposure to glyphosate formulations may either reduce (Estok et al., 1989; Sanogo et al., 2000; Diaz et al., 2003; Tanney and Hutchinson, 2010; Druille et al., 2013; Zaller et al., 2014) or rarely stimulate (Laatikainen and Heinonen-Tanski 2002; Diaz et al., 2003) proliferation of certain fungal species. Laboratory studies on cultured microorganisms are likely to overestimate toxicity effects (Estok et al., 1989), however. Field studies on the effect of glyphosate application on forest soil organisms and microbial processes are limited, and their findings are often contradictory. Some detrimental effects on fungal communities and nutrient cycling have been documented (Vitousek et al. 1992; Munson et al. 1993). Similarly, annual applications of glyphosate in an Ontario plantation over a 5-year period have resulted in reduced microbial biomass and carbon, and a reduced soil organic carbon ratio, which indicates a reduced capacity of the ecosystem to maintain its nutrient reservoir (Ohtonen et al., 1992). In contrast, other field studies have found minimal or no effect on microbial processes or fungal community structures (Chakravarty and Chatarpaul, 1990; Stratton and Steward, 1992; Busse et al., 2001; Haney et al., 2002; Houston et al., 2002), while others have found a short-term increase in microbial activity caused by the breakdown of glyphosate and AMPA (Wardle and Parkinson 1990; Haney et al., 2002; Ratcliff et al., 2006; Mijangos et al., 2009). The extent of the variation in results suggests that more research on forest applications of glyphosate is needed to better understand direct effects on microbial communities. Research should examine effects on individual species and indirect impacts resulting from these changes in the ecosystem.

3.2.3 Glyphosate/aminomethylphosphonic acid fate in water

The mandated use of pesticide-free zones around water features, the strong sorption of glyphosate to upper soil layers, and the rapid uptake of glyphosate by plants minimize the risk of the herbicide entering aquatic ecosystems. The main ways that glyphosate could enter aquatic ecosystems are by drift onto non-target areas or by soil particle mobilization after a storm event in the hours following glyphosate application (Rolando et al. 2017). These risks may be minimized in field operations by using electronic guidance systems, low drift nozzles, and meteorological monitoring of wind speed, air temperature, and humidity (Thompson et al., 2012). Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are implemented (Gluns, 1989; Feng and Thompson 1990; Thompson et al., 2004; Adams et al., 2007).

Most North American field studies in streams and wetlands have shown that if glyphosate moves into water sources, its DT50 is less than 5 days, and there are no detectable residues after 15 days (Newton et al., 1984, 1994; Gluns, 1989; Goldsborough and Beck, 1989; Wan et al., 1989; Feng and Thompson, 1990; Thompson et al., 2004; Adams et al., 2007). One study in boreal ponds found a half-life of up to 11 days (Goldsborough and Brown, 1993).

The primary mechanisms involved in the rapid breakdown or reduction of glyphosate in the water column are adsorption into benthic or suspended sediments, microbial breakdown of glyphosate and its breakdown products, and downstream dilution. Glyphosate persists longer in oligotrophic water bodies or those that are cold and deep and have low microbial activity. Residues have been detected in benthic sediments of these systems up to 18 months after glyphosate application (Newton et al., 1984, 1994; Feng et al., 1990).

3.3 Climate Change

The Intergovernmental Panel on Climate Change notes that "in the long-term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit" (Nabuurs et al., 2007). Vegetation management (including, but not limited to, glyphosate application) can affect carbon sequestration due to its impact on vegetation structure and stand productivity. When used to control herbaceous or shrub vegetation, for example, it allows the establishment of a woody crop, which delivers immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools.

When competing species are aspen or other deciduous species, however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with the site and species. Mixedwood stands comprised of spruce and aspen are likely to have a higher yield than either pure spruce or pure aspen stands because of differences in shade tolerance, phenology, rooting patterns, and physical space occupied by different sized canopies (McCulloch and Kabzems 2009; Gough et al., 2019). Retaining between 1000 and 10,000 sph of aspen is expected to increase total stand production by approximately 20% relative to a pure spruce stand, but this will be at the expense of spruce volume (Kabzems et al., 2007). Harper and Roach (2014) similarly report that in a modelled mixedwood, the total stand volume was higher in a spruce–aspen mixedwood than in pure spruce or pure aspen stands.

Growth and yield models for the SBS show that total stand volumes in lodegepole pine–aspen stands are not different from those in pure aspen or pure pine stands (Harper, 2015). In all cases, the increase in deciduous volume is at the expense of conifer volume (Kabzems et al., 2007; Harper and Roach, 2014; Harper, 2015; Harper, 2017).

Forest soils are the largest carbon pool in boreal and temperate ecosystems, often storing greater amounts of carbon than living biomass and coarse woody debris (Heath et al., 2003). Laganiere et al. (2017) found that aspen trees stored less carbon in the forest floor and similar amounts in the mineral soil relative to conifers. However, their study also showed that soil organic carbon stock under aspen was more stable, which rendered it more protected against environmental changes and soil disturbances.

A source of uncertainty in determining the difference in carbon sequestration between mixedwoods and pure conifer stands is the shorter lifespan of deciduous trees compared to conifers, which ultimately affects the amount of time that a stand can act as a carbon sink (Harper and Roach, 2014).

3.4 Wildfire

Vegetation management (including, but not limited to, glyphosate application) has the potential to alter the number of deciduous trees left on a site after regeneration. Deciduous stands often act as natural fire breaks. In summer, deciduous stands moderate microclimates, inhibit wind movement, help maintain lower air temperature and higher humidity, and maintain soil and surface fuel moisture longer into the fire season when compared to conifer-dominated stands (Chesterman, 1997). The Canadian Forest Fire Behaviour Prediction System predicts that it takes more extreme moisture conditions for high-intensity fires to build in deciduous fuel types than in coniferous fuel types (Taylor et al., 1996).

The physical properties of aspen, in particular, resist intense fire behaviour, which makes it a popular choice for fuel treatments in the wildland–urban interface throughout North America (Shepperd et al., 2006; Gray 2018). Generally, fire does not get carried into the crowns of deciduous stands due to the absence of ladder fuels. Consequently, fires in deciduous stands are usually slower moving surface fires, which are easier to suppress than crown fires (Alexander and Lanoville, 2004). The Forest Fire Behaviour Prediction System indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous[6] or leaf-on mixedwood stands. Among deciduous trees, poplars show the most fire resistance (Table 6).

The effect of fire behaviour associated with deciduous vegetation that is treated with glyphosate is not well documented. It is expected that the fire hazard in dead stems following either manual or chemical treatment would be high because dead aspen burns very hot (R.W. Gray, personal communication, 2019).

Table 6. Fire resistance of broad-leaved species (BC MFLNRORD 2019)

Fire resistance/resilience	Broad-leaved species
High	Balsam poplar, black cottonwood
High–Moderate	Gary oak, bigleaf maple
Moderate	Trembling aspen, red alder, paper birch
Low	Arbutus

3.5 First Nations

Some First Nations in B.C. have expressed concern over the use of glyphosate in forests. Some of these concerns relate to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated. Chief Ron Ignace (Skeetchestn Indian Band) has indicated that he considers the spraying of herbicide "an act of cultural genocide, because you are killing our foods and medicines."[7] The McLeod Lake Indian Band passed a Band Council resolution in July 2019 that reaffirms the Band's zero tolerance for herbicide, pesticide, insecticide, and chemical fertilizer use within the traditional territory. The resolution indicates that glyphosate is deemed carcinogenic and has a direct impact on wildlife, ecosystems, and water sources. Where there is doubt concerning the science about herbicides, there can be an inclination toward the precautionary principle.

Two-way education, communication, collaboration, and joint problem-solving between stakeholders is key to reaching agreements about land use. Traditional plant users should, for example, take into consideration that the presence of glyphosate does not indicate toxicity (Wood, 2019) or that plant diversity, richness, and abundance is not generally affected in the years following application. Similarly, forest managers need to acknowledge and communicate uncertainty regarding minor effects of glyphosate use. There is mounting evidence, for example, that glyphosate/AMPA may persist in low levels in some perennial plants (Wood, 2019), and

[6] During spring, before leaf-out in deciduous stands, the grass has the potential to dry out rapidly in the absence of canopy cover, which creates a higher surface fire potential until green-up and leaf-on occurs.
[7] https://acuriouslookatpoliticsinbc.blogspot.com/2019/09/adam-olsen-skeetchestn-indian-band.html?fbclid=IwAR3kXSjKGMzGu6V5qs4Gxvu9l06PdbVbL5TtjdfWvallemumCz0TiAsRnaQ

that it may also disrupt the creation of some plant secondary compounds, some of which may be the compounds responsible for medicinal effects in traditional medicines (Gomes et al., 2014).

Relationship building between licensees and First Nations takes time and effort, but proactive and informed engagement can often solve problems. Discussion at the land use planning stage can help build mutual understanding, and ensuring that stakeholders understand silvicultural concepts of vegetation competition and the need for brushing to re-establish some stands after harvest will lead to more productive discussions.

Engagement with First Nations can also be conducted through the referral process within a PMP, which calls for meaningful consultation and accommodation. Licensees have indicated that within this framework, efforts can be, and often are, made to accommodate the specific concerns of First Nations by:

- designating no-spray areas;
- prioritizing manual treatments;
- prioritizing backpack instead of aerial application;
- prioritizing spot spray around individual stems;
- increasing buffers;
- leaving untreated patches;
- providing alternative plant gathering sites;
- providing additional notification and signage; and
- adjusting treatment schedules to avoid disrupting First Nations activities.

3.6 Public Use

Forest managers are faced with mounting public pressure over the safety of glyphosate use (Thomson and Pitt, 2011). Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts on human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping, or hiking. The Canada Pest Management Regulatory Agency's review on glyphosate (PMRA, 2017) addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health. This applies to people who may come in contact with glyphosate through food or water, by handling the product, or by entering treated sites.

Currently, there is no evidence that suggests that glyphosate application can cause game meat contamination because glyphosate has not been shown to accumulate in animal tissues (including in game species such as moose, deer, and hare) (Newton et al., 1984; Legris and Couture, 1991; Lautenschlager, 1992). Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, localized primarily in roots but sometimes found in shoot and fruit tissue (Wood, 2019). Where detected, glyphosate residue levels averaged 0.79 ppm (the highest level detected was 4 ppm) 1 year after

application. From a food consumption perspective, 0.1 ppm is the maximum residue level allowed for non-designated food in Canada, although this value ranges from 0.08 to 40.00 for specific foods. While the persistence timeline in forest plants is not well understood, persistence is expected to be more transient than in agricultural settings because in forestry, glyphosate is typically used only once or twice over an entire rotation.

Better communication between forest managers and recreational users about the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, can help address key public concerns and build trust. On-site signage after glyphosate treatment, which is currently required in B.C. under IPMR sec 63.1 and outlines safety precautions, could be used to address some of the current knowledge gaps (Wood, 2019).

4 IMPACTS ON TIMBER SUPPLY

Vegetation control, including but not limited to glyphosate application, is necessary in some cases to supress competing vegetation and allow crop trees to become established and grow unimpeded. The unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests. Vegetation management is one key tool for meeting these objectives.

Glyphosate is used in this context because of its cost-effectiveness compared to manual vegetation control methods. Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in not satisfactorily restocked area, particularly problematic areas, with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

In Canada, decisions to not use chemical herbicides have been made in Quebec and Nova Scotia. In Quebec, a provincial ban of glyphosate use on Crown land took effect in 2001 after severe public pressure and a series of public consultations. Forest regeneration focuses on early planting of tall stock and intensive manual brushing. Since then, plantation establishment and tending costs have frequently exceeded $5000/ha due to planting large stock and to the need to apply as many as three manual brushing treatments (Labbé et al., 2014). Dampier et al. (2006) reported that cost per cubic metre of wood tripled when conifer release was performed by motor-manual methods rather than aerial application of herbicide.

In addition to the increases in reforestation costs, there were challenges in managing plantations where the objective was to maximize wood production (Thiffault and Roy, 2011). Manual brushing alone was not effective in controlling competing vegetation and did not promote optimal crop tree growth due to rapid resprouting or suckering of competitors and competition from herbaceous species. Since the glyphosate ban, the Quebec Chief Forester's Office has reported challenges in reaching proper stocking throughout the province. In some areas, more than half the plantations have failed to meet required stocking due to severe competition (Bureau du forestier en chef, 2015).

An audit of plantations in Nova Scotia after a decision was made to not use herbicides yielded similar findings. Following a survey of untreated plantations, 87% of conifer plantations were

considered failures (with less than 60% stocking), and only 3% met free-growing standards 6–8 years post-harvest (Nicholson, 2007).

In B.C., meeting free-growing stocking standards ensures that sustainable timber supply is achieved. In cases where aggressive competing vegetation cannot be overcome to the extent that is practicable to meet free-growing requirements, licensees may request relief from reforestation obligations under FPPR sec 97.1. Increasing the challenge to meet reforestation obligations on a broad scale may increase the risk of reduced plantation performance with significant timber supply impacts, such as in Quebec.

4.1 Managing for Multiple Values

Forest management decisions related to achieving landscape objectives are reflected in stocking standards. Where stocking standards require the re-establishment of coniferous forests after harvest, with the objective of maintaining healthy forests and long-term fibre supply, studies show that competing vegetation control is necessary in some cases and that glyphosate is a highly effective vegetation control tool that has minimal and transient impacts on the ecosystem.

Where non-timber objectives such as increasing broadleaf stand components for wildfire risk reduction or wildlife are identified as priorities, current free-growing stocking standards may be overly restrictive (Harper and Roach, 2014). License holders have indicated that more flexibility and better guidance and support for alternative stocking standards could facilitate reduced brushing (including but not limited to glyphosate use) and accommodate other non-timber values. An example of one such mechanism is the Fort St. John pilot project, which allows for 2 ha, or 20%, of not satisfactorily restocked area over the landscape. The concept allows for areas of poor performance to be compensated by areas of superior performance, which in turn allows greater flexibility and efficiency of resources in areas where higher yields can be achieved, and avoids expensive, poor-value treatments, while accommodating non-timber values.

Landscape-level plans that link objectives to operational plans with a rationale for stocking standards could provide priorities for competing objectives on the land base.[8] For example, stocking standards in areas where managing for wildfire breaks or wildlife habitat are identified as priorities need to reflect a higher acceptance of broadleaf species over conifers, with the understanding that timber supply may be negatively affected. There are ongoing efforts to further develop standards that facilitate deciduous management in the context of overall forest management objectives. One example is the inclusion of fire stocking standards in the wildland–urban interface, including the establishment and management of deciduous species to reduce fire behaviour in areas near communities and infrastructure. In another example, a Hardwood Management Strategy was developed in 2008 to facilitate management of red alder, bigleaf maple, and birch in the Coast Region. Wildlife stocking standards are also being developed, and regional guidance is available.

[8] Challenges in addressing multiple forest management objectives such as timber supply, biodiversity, resilience, etc. at the operational level are identified in the Forest Practices Board's (2019) Special Report, *Tactical Forest Planning: The Missing Link Between Strategic and Operational Planning in BC.*

Alternative stocking standards for a Forest Stewardship Plan must be supported with science and justified with timber supply considerations and other tests as per FPPR 26(5). In some parts of the province, the focus on coniferous species remains a hurdle to applying alternative standards because the science for deciduous management is not well understood at the operational level. Licensees have indicated that further supporting research and guidance, such as that found in Newsome and Heineman's (2016) mixedwood stocking standards for the Cariboo Region, would assist them in developing stocking standards that can better incorporate other non-conifer values.

5 RECOMMENDATIONS

s.13

6 CONCLUSIONS

Glyphosate is one of many vegetation management tools available to forest managers. It is used to help maintain plantation survival and to meet free-growing obligations that ensure stand productivity and sustainable timber supply. Forest managers are faced with mounting public pressure over the perceived environmental impacts of forestry applications of glyphosate—in particular, concerns over the removal of broadleaf tree species from the landscape and the consequent impacts on risk of wildfire, wildlife habitat, resiliency, climate change, etc. A review of current inventory data, however, shows that stands that have been treated with glyphosate retain 15–21% deciduous components at free growing, and that the area comprised of deciduous–mixed stands has been increasing over time as a result of forest management activities in general.

Field studies have also shown that the effects of glyphosate and its metabolites on the environment are minimal when the herbicide is applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes to communities tend be transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects of glyphosate on soil microorganisms, its chelating effects on soil and plant nutrients, and its persistence in plants that survive treatment. More research is still needed to understand some of the impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.

While more research on the identified knowledge gaps is recommended, the use of glyphosate needs to be viewed from a landscape perspective, considering the amount of area treated, the short time scale of stand-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape levels. Put into perspective, vegetation management is just one component of the many silvicultural decisions that affect forest management in B.C. Many of the challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by building better linkages between site- and landscape-level planning that allows other non-timber values to be prioritized where needed.

7 REFERENCES

Adams, G. W., Smith, T., & Miller, J. D. (2007). The absence of glyphosate residues in wet soil and the adjacent watercourse after a forestry application in New Brunswick. *Northern Journal of Applied Forestry, 24*(3), 230–232.

Alexander, M. E., & Lanoville, R. A. (2004). The International Crown Fire Modelling Experiment fuel treatment trials [Abstract]. In R .T. Engstrom, K.E.M. Galley, & W.J. de Groot (Eds.). *Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems* (222). Tallahassee, FL : Tall Timbers Research Station.

Baker, L. F., Mudge, J. F., Houlahan, J. E., Thompson, D. G., & Kidd, K. A. (2014). The direct and indirect effects of a glyphosate-based herbicide and nutrients on Chironomidae (Diptera) emerging from small wetlands. *Environmental Toxicology and Chemistry, 33*, 2076–2085.

Baker, L. F., Mudge, J. F, Thompson, D. G, Houlahan, J. E, & Kidd, K. E. (2016). The combined influence of two agricultural contaminants on natural communities of phytoplankton and zooplankton. *Ecotoxicology , 25*, 1021–1032.

Bell, F. W., & Newmaster, S. G. (2002). The effects of silvicultural disturbances on the diversity of seed-producing plants in the boreal mixedwood forest. *Canadian Journal of Forest Research, 32*(7), 1180–1191. Retrieved from https://digitalcommons.usu.edu/aspen_bib/389

Bell, F.W., and Newmaster, S.G. (1998). Falling snow ecosystem project: floral richness, abundance and diversity. In Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability—Popular Summaries, 1998, Sault Ste.-Marie, Ont. Compiled by R.G. Wagner and D.G. Thompson. Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, Ont. For. Res. Inf. Pap. 141. pp. 45–47

Biring, B. S., Comeau, P. G., & Fielder, P. (2003). Long-term effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia. *Annals of Forest Science, 60*(7), 681-690.14.
Biring, B. S., & Hays-Byl, W. J. (2000). *Ten-year conifer and vegetation responses to glyphosate treatment in the SBSdw3*. (Extension Note 46). Victoria, BC: B.C. Ministry of Forests.

Biring, B. S., Hays-Byl, W. J., & Hoyles, S. E. (1999). *Twelve-year conifer and vegetation responses to discing and glyphosate treatments on a BWBSmw backlog site* (Working Paper 43). Victoria, BC: B.C. Ministry of Forests.

Boateng, J. O., Heineman, J. L., McClarnon, J., & Bedford, L. (2006).Twenty year responses of white spruce to mechanical site preparation and early chemical release in the boreal region of northeastern British Columbia. *Canadian Journal of Forest Research, 36*, 2386–2399.

British Columbia Ministry of Forests, Lands and Natural Resource Operations (BC MFLNRO). (2008). *Tree species composition and diversity in British Columbia* (FREP Report #14). Victoria, BC.

British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development (BC MFLNRORD). (2018). *Silviculture surveys procedures manual: regen delay, stocking and free growing surveys plus alternative survey methodologies*. Victoria, BC. Retrieved from https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

Bureau du forestier en chef. (2015). Succes des plantations. Avis du Forestier en chef. FEC-AVIS-04-2015, Roberval, Québec.

Busse, M. D., Ratcliff, A. W., Stestak, C.J., & Powers, R. F. (2001). Glyphosate toxicity and the effects of long-term vegetation control on soil microbial communities. *Soil Biology & Biochemistry, 33*, 1777–1789.

Canadian Council of Ministers of the Environment (CCME). (2012). Canadian water quality guidelines for the protection of aquatic life: glyphosate. In *Canadian environmental quality guidelines*. Winnipeg , MB.

Cakmak, I., Yazici, A., Tutus, Y., & Ozturk, L. (2009). Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium, and iron in non-glyphosate resistant soybean. *European Journal of Agronomy, 31*(3), 114–119.

Chakravarty, P. , & Chatarpaul, L. (1990). Non-target effect of herbicides: II. The influence of glyphosate on ectomycorrhizal symbiosis of red pine (*Pinus resinosa*) under greenhouse and field conditions. *Pesticide* S*cience*, *28*(3), 243–247.

Chesterman, D. A. 1997. *Microclimate of aspen forests*. (Unpublished master's thesis). University of Alberta, Edmonton, AB.

Cole, E., Youngblood, A., & Newton, M. (2003). Effects of competing vegetation on juvenile white spruce (*Picea glauca*(Moench)Voss) growth in Alaska. *Annals of Forest Science, 60*, 1–11.

Comeau, P.G., Braumandl, T.F. and Xie, C.Y. (1993). Effects of overtopping vegetation on light availability and growth of Engelmann spruce (Picea engelmannii) seedlings. *Canadian Journal of Forest Research*, 23(10), pp.2044-2048.

Comeau, P. G., Biring, B. S., & Harper, G. J. (1999). *Conifer response to brushing treatments: a summary of British Columbia data* (Extension Note 41). Victoria, BC: B.C. Ministry of Forests.

Comeau, P. G., Biring, B. S., & Harper, G. J. (2000). Effectiveness of repeated manual cutting and glyphosate for release of Engelmann spruce from mixed-shrub herb vegetation. *Western Journal of Applied Forestry, 15*(3), 154–162. http://dx.doi.org/10.1093/wjaf/15.3.154

Comeau, P., & Fraser, E. (2018). Plant community diversity and tree growth following single and repeated glyphosate herbicide applications to a white spruce plantation. *Forests, 9*(3), 107.

Comeau, P. G., & Harper, G. J. (2009). Effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia Year 15 results. *Forestry Chronicle, 85*(4), 583–592.

Comeau, P. G., Harper, G., Blache, M. E., Boateng, J. O., & Gilkeson, L. (1996). Integrated forest vegetation management: options and applications. In P. G. Comeau, G. J. Harper, M. E. Blache, J. O. Boateng, & L. A. Gilkeson (Eds.). *Proceedings of the Fifth B.C. Forest Vegetation Management Workshop* (FRDA Report 51). Victoria, BC: B.C Ministry of Forests & B.C, Ministry of Environment, Lands and Parks.

Connor, J. F., & McMillan, L. M. (1990). *Winter utilization by moose of glyphosate-treated cutovers*. Toronto, ON: Ontario Ministry of Natural Resources.

Custer, T. W., Cox, E., & Gray, B. (2004). Trace elements in moose (*Alces alces*) found dead in northwestern Minnesota, USA. *Science of the Total Environment, 330*(1), 81–87.

Dampier, E. E., Bell, F. W., St-Amour, M., Pitt, D. G., & Luckai, N. J. (2006). Cutting versus herbicides: tenth-year volume and release cost-effectiveness of sub-boreal conifer plantations. *Forestry Chronicle, 82*(4), 521–528. Retrieved from https://pubs.cif-ifc.org/doi/10.5558/tfc82521-4

Diaz, G., Carrillo, C., & Honrubia, M. (2003). Differential responses of ectomycorrhizal fungi to pesticides in pure culture. *Cryptogamie Mycologie, 24*, 199–211.

Druille, M., Cabello, M. N., Omacini, M., & Golluscio, R. A. (2013). Glyphosate reduces spore viability and root colonization of arbuscular mycorrhizal fungi. *Applied Soil Ecology, 64*, 99–103.

Duke, S. O., Lydon, J., Koskinen, W. C., Moorman, T. B., Chaney, R. L., & Hammerschmidt, R. (2012). Glyphosate effects on plant mineral nutrition, crop rhizosphere microbiota, and plant disease in glyphosate-resistant crops. *Journal of Agricultural and Food Chemistry, 60*(42), 10375–10397.

Duke, S. O., Rimando, A. M., Reddy, K. N., Cizdziel, J. V., Bellaloui, N., Shaw, D. R., Williams, M. M., & Maul, J. E. (2018). Lack of transgene and glyphosate effects on yield, and mineral and amino acid content of glyphosate-resistant soybean. *Pest Management Science, 74*(5), 1166–1173.

Dunbar, J., McCulloch, L., & Kabzems, R. (2011). Bluejoint stand establishment decision aid. *Journal of Ecosystems and Management, 11*(3).

Durkin, P. R. (2003). *Glyphosate - human health and ecological risk assessment report*. Fayetteville, NY: Syracuse Environmental Research Associates Inc.

Edge, C. B., Gahl, M. K., Pauli, B. D, Thompson, D. G., & Houlahan, J.E. (2011). Exposure of juvenile green frogs (*Lithobates clamitans*) in littoral enclosures to a glyphosate-based herbicide. *Ecotoxicology and Environmental Safety, 74*, 1363–1369.

Edge, C., Gahl, M., Thompson, D., Hao, C., & Houlahan, J. (2014a). Variation in amphibian response to two formulations of glyphosate-based herbicides. *Environmental Toxicology and Chemistry, 33,* 2628–2632.

Edge, C. B., Gahl, M. K., Thompson, D. G., & Houlahan, J. E. (2013). Laboratory and field exposure of two species of juvenile amphibians to a glyphosate-based herbicide and *Batrachochytrium dendrobatidis*. *Science of the Total Environment, 444*, 145–152.

Edge, C. B., Thompson, D. G., Hao, C., & Houlahan, J. E. (2012). A silviculture application of the glyphosate-based herbicide VisionMAX to wetlands has limited direct effects on amphibian larvae. *Environmental Toxicology and Chemistry, 31*, 2375–2383.

Edge, C., Thompson, D., Hao, C., & Houlahan, J. (2014b). The response of amphibian larvae to exposure to a glyphosate-based herbicide (Roundup WeatherMax) and nutrient enrichment in an ecosystem experiment. *Ecotoxicology and Environmental Safety, 109*, 124–132.

Edginton, A. N., Sheridan, P. M., Stephenson, G. R., Thompson, D. G., & Boermans, H. J. (2004). Comparative effects of pH and Vision® herbicide on two life stages of four anuran amphibian species. *Environmental Toxicology and Chemistry: An International Journal*, *23*(4), 815–822.

Ehrentraut, G., & Brantner, K. (1990). Vegetation management by manual and mechanical means in Alberta boreal forests. *Forestry Chronicle, 66*, 366–368.

Eker, S., Ozturk, L., Yazici, A., Erenoglu, B., Romheld, V., & Cakmak, I. (2006). Foliar-applied glyphosate substantially reduced uptake and transport of iron and manganese in sunflower (*Helianthus annuus* L.) plants. *Journal of Agricultural and Food Chemistry, 54*(26), 10019–10025.

Eremko, R.D. (1986). *The effects of the aerial application of Roundup on water quality in the Nicoamen River watershed*. Unpublished report. B.C. Ministry of Forests and Lands, Lillooet District.

Eschholz, W. E., Servello, F. A., Griffith, B., Raymond, K. S., & Krohn, W. B. (1996). Winter use of glyphosate-treated clearcuts by moose in Maine. *Journal of Wildlife Management, 60*, 764–769.

Estok, D., Freedman, B., & Boyle, D. (1989). Effects of the herbicides 2,4-D, glyphosate, hexazinone, and triclopyr on the growth of three species of ectomycorrhizal fungi. *Bulletin of Environmental Contamination and Toxicolology, 42*(6), 835–839. doi:10.1007/BF01701623

Feng, J. C., & Thompson, D. G. (1990). Fate of glyphosate in a Canadian forest watershed. 2. Persistence in foliage and soils. *Journal of Agricultural and Food Chemistry, 38*(4), 1118–1125.

Feng, J. C., Thompson, D. G., & Reynolds, P.E. (1990). Fate of glyphosate in a Canadian forest watershed. 1. Aquatic residues and off-target deposit assessment. *Journal of Agricultural and Food Chemistry, 38*(4), 1110–1118.

Flynn, A., Franzmann, A. W., Arneson, P. D., & Oldemeyer, J. L. (1977). Indications of copper deficiency in a subpopulation of Alaskan moose. *Journal of Nutrition, 107*(7), 1182–1189.

Folmar, L. C., Sanders, H. O., & Julin, A. M. (1979). Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. *Archives of Environmental Contamination and Toxicology, 8*(3), 269–278. https://doi.org/10.1007/BF01056243

Frank, A., Galgan, V., & Petersson, L. R. (1994). Secondary copper deficiency, chromium deficiency and trace element imbalance in the moose (*Alces alces* L.): effect of anthropogenic activity. *Ambio, 23*(4–5), 315–317.

Freedman, B., Morash, R., & MacKinnon, D. (1993). Short-term changes in vegetation after the silvicultural spraying of glyphosate herbicide onto regenerating clearcuts in Nova Scotia, Canada. *Canadian Journal of Forest Research, 23*(10), 2300–2311.

Frey, B. R., Lieffers, V. J., Landhäusser, S. M., Comeau, P. G., & Greenway, K. J. (2003). An analysis of sucker regeneration of trembling aspen. *Canadian Journal of Forest Research, 33*(7), 1169–1179.

Giesy, J. P., Dobson, S., & Solomon, K. R. (2000). Ecotoxicological risk assessment for Roundup® herbicide. In G.W. Ware (Ed.). *Reviews of environmental contamination and toxicology*. (Vol 167, 35–120). New York, NY: Springer.

Gluns, D. R. (1989). *Herbicide residue in surface water following an application of Roundup® in the Revelstoke Forest District* (RR 88001-NE). B.C. Ministry of Forests and Lands.

Goldsborough, L. G., & Beck, A. E. (1989). Rapid dissipation of glyphosate in small forest ponds. *Archives of Environmental Contamination and Toxicology*, *18*(4), 537–544.

Goldsborough, L. G., & Brown, D. J. (1993). Dissipation of glyphosate and aminomethylphosphonic acid in water and sediments of boreal forest ponds. *Environmental Toxicology and Chemistry 12*(7), 1139–1147.

Gomes, M. P., Smedbol, E., Chalifour, A., Hénault-Ethier, L., Labrecque, M., Lepage, L., Lucotte, M., & Juneau, P. (2014). Alteration of plant physiology by glyphosate and its by-product aminomethylphosphonic acid: an overview. *Journal of Experimental Botany*, *65*(17), 4691–4703.

Gough, C. M, Atkins, J. W., Fahey, R. T., & Hardaman, B.S. (2019). High rates of primary production in structurally complex forests. *Ecology, 100*(10). https://doi.org/10.1002/ecy.2864

Gray, R. W. (2018). *Trembling aspen stands as firebreaks: what options are available for stimulating aspen stand expansion*. Cranbrook, BC: UBCM Fuel Management Pilot Program. Retrieved from https://wfca.ca/wp-content/uploads/2018/06/Trembling-Aspen-Stands-as-Firebreaks_FINAL-REPORT.pdf

Guynn, D. C., Guynn, S. T., Wigley, T. B., & Miller, D. A. (2004). Herbicides and forest biodiversity: What do we know and where do we go from here? *Wildlife Society Bulletin, 32*(4), 1085–1092.

Hagner, M., Mikola, J., Saloniemi, I., Saikkonen, K., & Helander, M. (2019). Finnish ecological sustainability study: glyphosate-based Roundup herbicide has 'minor, transient' impacts on soil and animal health. *Scientific Reports 9*(1), 8540. doi.org/10.1038/s41598-019-44988-5

Haney, R. L., Senseman, S. A., & Hons, F. M. (2002). Effect of Roundup Ultra on microbial activity and biomass from selected soils. *Journal of Environmental Quality*, *31*(3), 730–735.

Harper, G. J. (2015). Lodgepole pine and trembling aspen mixedwoods: growth and yield within 22 to 39 year old pine plantations of northern interior British Columbia. *Forestry Chronicle, 91*(5), 502–518.

Harper, G. (2017). Lodgepole pine and trembling aspen competition: neighbourhood studies within 22 to 39 year old pine plantations of northern British Columbia. *Forestry Chronicle, 93*{3), 226–240. https:// doi .org/10.5558/tfc2017-031

Harper, G. J., Biring, B. C., & Heineman, J. (1997). *Mackay River herbicide trial: conifer response 9 years post-treatment* (Research Report 11). B.C. Ministry of Forest.

Harper, G. J., Comeau, P. G., & Biring, B. S. (2005). A comparison of herbicide and mulch mat treatments for reducing grass, herb, and shrub competition in the B.C. Interior Douglas-fir zone—ten-year results. *Western Journal of Applied Forestry, 20*(3), 167–176.

Harper, G., & Roach, J. (2014). *The role of broadleaf trees: impacts of managing boreal and sub-boreal mixedwood forests in British Columbia* (Extension Note 110). Victoria, BC: B.C. Ministry of Forests and Range.

Hart, D., & Comeau, P.G. (1992). *Manual brushing for forest vegetation management in British Columbia: a review of current knowledge and information needs* (Land Management Report 77). Victoria, BC: B.C. Ministry of Forests.

Hawkins, C. D. B., Dhar, A., & Lange, J. (2013). Vegetation management with glyphosate has little impact on understory species diversity or tree growth in a sub boreal spruce plantation—a case study. *Plant Biosystems, 147*(1), 105–114.

Heath, L. S., Kimble, J. M., Birdsey, R. A., & Lal, R. (2003). The potential of U.S. forest soils to sequester carbon. In J. M. Kimble, L. S. Heath, R. A. Birdsey, & R. Lal (Eds.). *The potential of U.S. forest soils to sequester carbon and mitigate the greenhouse effect* (385–394). Boca Raton: CRC Press.

Heineman, J. L., Simard, S. W., Sachs, D. L., & Mather, W. J. (2005). Chemical, grazing, and manual cutting treatments in mixed herb-shrub communities have no effect on interior spruce survival or growth in southern interior British Columbia. *Forest Ecology and Management, 205*(1–3), 359–374. https:// doi .org/10.1016/j. foreco.2004.10.038

Hjeljord, O., & Grønvold, S. (1988). Glyphosate application in forest—ecological aspects: VI. Browsing by moose (*Alces alces*) in relation to chemical and mechanical brush control. *Scandinavian Journal of Forest Research*, *3*(1–4), 115–121.

Houlahan, J. E., Findlay, C. S., Schmidt, B. R., Meyer, A. H., & Kuzmin, S. L. (2000). Quantitative evidence for global amphibian population declines. *Nature, 404*, 752–755.

Houston, A. P. C., Visser, S., & Lautenschlager, R. A. (2002). Response of microbial processes and fungal community structure to vegetation management in mixedwood forest soils. *Canadian Journal of Botany, 76*(12), 2002–2010.

Howe, C. M., Berrill, C. M., Pauli, B. D., Helbing, C. C., Werry, K., & Veldhoen, N. (2004). Toxicity of glyphosate-based pesticides to four North American frog species. *Environmental Toxicology and Chemistry, 23*, 1928–1938.

Kabzems R., & Harper, G. J. (2015). *Conifer and vegetation responses to pre-planting applications of glyphosate and hexazinone on a boreal backlog site, Sx trial 82502g-2* (Technical Report 087). Victoria, BC: Province of British Columbia. Retrieved from www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr087.htm

Kabzems, R., Nemec, A. L., & Farnden, C. (2007). Growing trembling aspen and white spruce intimate mixtures: early results (13–17 years) and future projections. *BC Journal of Ecosystems and Management, 8*(1), 1–14. Retrieved from http://www.forrex.org/publications/jem/ISS39/vol8 no1 artl.pdf

Kissane, Z., & Shephard, J. M. (2017). The rise of glyphosate and new opportunities for biosentinel early-warning studies. *Conservation Biology, 31*(6), 1293–1300.

Kuzyk, G., Marshall, S., Procter, C., Schindler, H., Schwantje, H., Gillingham, M., Hodder, D., White, S., & Mumma, M. (2018). *Determining factors affecting moose population change in British Columbia: testing the landscape change hypothesis. 2018 progress report: February 2012–April 2018* (Wildlife Working Report No. WR-126). Victoria, BC: B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Laatikainen, T., & Heinonen-Tanski, H. (2002). Mycorrhizal growth in pure cultures in the presence of pesticides. *Microbiological Research 157*(2), 127–137. doi: 10.1078/0944-5013-00139

Labbé, F., Lainesse, M., Nadeau, F-R., Prégent, G., & Savary, A. (2014). Analyse de rentabilité économique des plantations d'épinette noire et blanche et de pin gris. Bureau de mise en marché des bois, Québec (Québec). Retrieved from https://www.bmmb.gouv.qc.ca/analyses-economiques/

Laganiere, J., Boca, A., Van Miegroet, H., & Pare, D. (2017). A tree species effect on soil that is consistent across the species' range: the case of aspen and soil carbon in North America. *Forests, 8*, 113.

Lanctot, C., Navarro-Martin, L., Robertson, C., Park, B., Jackman, P., Pauli, B. D., & Trudeau, V. L. (2014). Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frog (*Lithobates sylvaticus*) tadpoles. II: Agriculturally relevant exposures to Roundup WeatherMax® and Vision® under laboratory conditions. *Aquatic Toxicology, 154*, 291–303.

Lanctot, C., Robertson, C., Navarro-Martin, L., Edge, C., Melvin, S. D., Houlahan, J., & Trudeau, V. L. (2013). Effects of the glyphosate-based herbicide Roundup WeatherMax® on metamorphosis of wood frogs (*Lithobates sylvaticus*) in natural wetlands. *Aquatic Toxicology, 140–141*, 48–57.

Lautenschlager, R. A. (1992). Effects of conifer release with herbicides on moose: browse production, habitat use, and residues in meat. *Alces, 28*, 215–222.

Lautenschager, R. A. (1993). Response of wildlife to forest herbicide applications in northern coniferous ecosystems. *Canadian Journal of Forest Research 23*, 2286–2299.

Lautenschlager, R. A., Dalton, W. J., Cherry, M. L., & Graham, J. L. (1999). Conifer release alternatives increase aspen forage quality in northwestern Ontario. *Journal of Wildlife Management, 63,* 1320–1326.

Lautenschlager, R. A., & Sullivan, T. P. (2002). Effects of herbicide treatments on biotic components in regenerating northern forests. *Forestry Chronicle,* 78, 1–37.

Legris, J., & Couture, G. (1991). Residus de Glyphosate dans le Gibier (Lievre, Orignal Qt cerf de Virginie) Suite a des Pulverisations en Milieu Forestier en 1988; Quebec Ministere des Forest, Direction de I' evaluation Environnementale: Charlesbourg, QC.

Lindgren, P. M. F., & Sullivan, T. P. (2001).Influence of alternative vegetation management treatments on conifer plantation attributes: abundance, species diversity, and structural diversity. *Forest Ecology and Management, 142*(1–3), 163–182.

Linz GM, Bleier WJ, Overland JD, Homan HJ. (1999). Response of invertebrates to glyphosate-induced habitat alterations in wetlands. *Wetlands,* 19, 220–227.

Macadam, A., & Kabzems, R. (2006). Vegetation management improves early growth of white spruce more than mechanical site preparation treatments. *Northern Journal of Applied Forestry*, 23(1), 35–46. https://doi.org/10.1093/njaf/23.1.35

McCulloch, L., & Kabzems, R. (2009). British Columbia's northeastern forests: aspen complex stand establishment decision aid. *BC Journal of Ecosystems and Management, 10*(2), 51–58. Retrieved from https://jem-online.org/index.php/jem/article/view/419

Meidinger, D. V., & Pojar, J. (1991). *Ecosystems of British Columbia* (Special Report Series 6). Victoria, BC: B.C. Ministry of Forests.

Mertens, M., Höss, S., Neumann, G., Afzal, J., & Reichenbecher, W. (2018). Glyphosate, a chelating agent—relevant for ecological risk assessment. *Environmental Science and Pollution Research, 25*(6), 5298–5317.

Mesnage, R., Defarge, N., De Vendômois, J.S., & Seralini, G.E. (2015). Potential toxic effects of glyphosate and its commercial formulations below regulatory limits. *Food and Chemical Toxicology, 84*, 133–153.

Mijangos, I., Becerril, J. M., Albizu, I., Epelde, L., & Garbisu, C. (2009). Effects of glyphosate on rhizosphere soil microbial communities under two different plant compositions by cultivation-dependent and-independent methodologies. *Soil Biology and Biochemistry*, *41*(3), 505–513.

Miller, D. T. (1985). Conifer release in the inland northwest – effects. In *Weed control for forest productivity in the interior west*. *Symposium Proceedings* (17–24). Spokane, WA: Washington State University.

Morgan, M. J., & Kiceniuk, J. W. (1992). Response of rainbow trout to a two month exposure to Vision®, a glyphosate herbicide. *Bulletin of Environmental Contamination and Toxicology, 48*, 772–780.

Munson, A. D., Margolis, H. A., & Brand, D. G. (1993). Intensive silvicultural treatment: impacts on soil fertility and planted conifer response. *Soil Science Society of America Journal*, *57*(1), 246–255.

Nabuurs, J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., Elsiddig, E., FordRobertson, J., Frumhoff, P., Karjalainen, T., Krankina, O., Kurz, W., Matsumoto, M., Oyhantcabal, W., Ravindranath, N., Sanz, M. Sanchez, T., & Zhang, X. (2007). Forestry. In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds). *Climate change 2007: mitigation*. Contribution of Working Group Ill to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Navarro-Martin, L., Lanctot, C., Jackman, P., Park, B. J., Doe, K., Pauli, B. D., & Trudeau, V. L. (2014). Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frogs (*Litho bates sylvaticus*) tadpoles. 1: Chronic laboratory exposures to Vision Max®. *Aquatic Toxicology, 154*, 278–290.

Navratil, S., Branter, K., & Zasada, J. (1991). Regeneration in the mixedwoods. In A. Shortreid (Ed.). *Proceedings of the Symposium on Northern Mixedwoods '89* (32–48). (FRDA Report 164). Victoria, BC: Forestry Canada, Pacific Forestry Centre.

Newsome, T. A., & Heineman, J. L. (2016). Adjusting free-growing guidance regarding aspen retention in the Cariboo-Chilcotin: research to operational implementation (Technical Report 102). Victoria, B.C: Province of British Columbia. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/TR102.htm

Newton, M., Cole, E. C., Lautenschlager, R. A., White, D. E., & McCormack, M. L., Jr. (1989). Browse availability after conifer release in Maine's spruce-fir forests. *Journal of Wildlife Management, 53*, 643–649.

Newton, M., Horner, L. M., Cowell, J. E., White, D. E., & Cole, E. C. (1994). Dissipation of glyphosate and aminomethylphosphonic acid in North American forests. *Journal of Agricultural and Food Chemistry, 42*(8), 1795–1802.

Newton, M., Howard, K. M., Kelpsas, B. R., Danhaus, R., Lottman, C. M., & Dubelman, S. (1984). Fate of glyphosate in an Oregon forest. *Journal of Agricultural and Food Chemistry, 32*,1144–1151.

Nicholson, J. (2007). *Survey of plantations established between 1998–2000 (6–8 years of age) on eastern Crown land without herbicides* (Forest Research Report 83). Nova Scotia Department of Natural Resources.

O'Hara, T. M., Carroll, G., Barboza, P., Mueller, K., Blake, J., Woshner, V., & Willetto, C. (2001). Mineral and heavy metal status as related to a mortality event and poor recruitment in a moose population in Alaska. *Journal of Wildlife Diseases, 37*(3), 509–522.

Ohtonen, R., Munson, A., & Brand, D. (1992). Soil microbial community response to silvicultural intervention in coniferous plantation ecosystems. *Ecological Applications*, *2*(4), 363–375.

Perala, D. A. (1985). *Using glyphosate herbicide in converting aspen to conifers* (Research Paper NC-259). St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.

Pesticide Management Regulatory Agency (PMRA). (2015). *Glyphosate revaluation decision RVD2015-1*. Health Canada.

Pesticide Management Regulatory Agency (PMRA). (2017). *Glyphosate revaluation decision RVD2017-1*. Health Canada.

Pesticide Management Regulatory Agency (PMRA). (2019). Statement from Health Canada on glyphosate. Health Canada. Retrieved from https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

Pitt, D. G., & Bell, F. W. (2005). Juvenile response to conifer release alternatives on aspen–white spruce boreal mixedwood sites. Part I: Stand structure and composition. *Forestry Chronicle, 81*(4), 538–547.

Pitt, D. G., Mihajlovich, M., & Proudfoot, L. M. (2004b). Juvenile stand responses and potential outcomes of conifer release efforts on Alberta's spruce aspen mixedwood sites. *Forestry Chronicle, 80*(5), 583–597.

Pitt, D. G., Wagner, R. G., & Towill, W. D. (2004a).Ten years of vegetation succession following ground-applied release treatments in young black spruce plantations. *Northern Journal of Applied Forestry 21*(3), 123–134.

Ratcliff, A. W., Busse, M. D., & Shestak, C.J. (2006). Changes in microbial community structure following herbicide (glyphosate) additions to forest soils. *Applied Soil Ecology*, *34*(2–3), 114–124.

Raymond, K. S., Servello, F. A., Griffith, B., & Eschholz, W. E. (1996). Winter foraging ecology of moose onglyphosate-treated clearcuts in Maine. *Journal of Wildlife Management, 60*, 753–763.

Reddy, K. N., Rimando, A. M., & Duke, S. O. (2004). Aminomethylphosphonic acid, a metabolite of glyphosate, causes injury in glyphosate-treated, glyphosate-resistant soybean. *Journal of Agricultural and Food Chemistry*, 52, 5139–5143.

Reynolds, P . E., Scrivener, J. C., Holtby, L. B., & Kingsbury, P. D. (1993). Review and synthesis of Carnation Creek herbicide research. *Forestry Chronicle, 69*(3), 323–330.

Rolando, C. A., Baillie, B. R., Thompson, D. G., & Little, K. M . (2017). The risks associated with glyphosate-based herbicide use in planted forests. *Forests, 8*(6), 208–233. Retrieved from https://www.mdpi.com/1999-4907/8/6/208

Rzymski, P., Klimaszyk, P., Kubacki, T., & Poniedziałek, B. (2013). The effect of glyphosate-based herbicide on aquatic organisms – a case study. *Limnological Review, 13*(4), 215–220.

Sanogo, S., Yang , X. B., & Scherm, H. (2000). Effects of herbicides on Fusarium solanif. sp. glycines and development of sudden death syndrome in glyphosate-tolerant soybean. *Phytopathology, 90*(1), 57–66. doi: 10.1094/PHYTO.2000.90.1.57

Santillo, D. J., Leslie, D. M., Jr., & Brown, P. W. (1989). Responses of small mammals and habitat to glyphosate application on clearcuts. *Journal of Wildlife Management, 53*, 164–172.

Shepperd, W. D., Rogers, P. C., Burton, D., & Bartos, D. L. (2006). *Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada* (General Technical Report RMRS-GTR-178). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Simard, S. (2001). *Effects of operational brushing on conifers and plant communities in the Southern Interior of British Columbia: results from PROBE 1991–2000, PRotocol for Operational Brushing* (Land Management Handbook 48). Victoria, BC: B.C. Ministry of Forests. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh48.pdf

Stratton, G.W. and Stewart, K.E., (1992). Glyphosate effects on microbial biomass in a coniferous forest soil. Environmental toxicology and water quality, 7(3), 223-236.

Sullivan, T.P., Wagner, R.G., Pitt, D.G., Lautenschlager, R.A., and Chen, D.G. (1998). Changes in diversity ofplant and small mammal communities after herbicide application in sub-boreal spruce forest. Canadian Journal of Forest Research, 28, 168–177.

Sullivan, T. P., & Sullivan, D. S. (2003). Vegetation management and ecosystem disturbance impact of glyphosate herbicide on plant and animal diversity in terrestrial ecosystems. *Environmental Review, 11*, 37–59.

Székács, A., & Darvas, B. (2012). Forty years with glyphosate. In M. N. A. E.-G. Hasaneen (Ed.). *Herbicides – properties, synthesis and control of weeds*. InTech: Rijeka, Croatia.

Tanney, J. B., & Hutchison, L. J. (2010). The effects of glyphosate on the in vitro linear growth of selected microfungi from a boreal forest soil. *Canadian Journal of Microbiology, 56*(2), 138–144.

Tarazona, J. V., Court-Marques, D., Tiramani, M., Reich, H., Pfeil, R., lstace, F., & Crivellente, F. (2017). Glyphosate toxicity and carcinogenicity: a review of the scientific basis of the European Union assessment and its differences with IARC. *Archives of Toxicology, 91*(8), 2723–2743.

Taylor, S. W., Pike, R. G., & Alexander, M. E. (1996). *Field guide to the Canadian forest fire behaviour prediction (FPB) system* (FRDA Handbook 012). Victoria, BC: Canadian Forest Service and B.C. Ministry of Forests. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/Docs/Frh/Frh012.pdf

Tesfamariam, T., Bott, S., Cakmak, I., Römheld, V., & Neumann, G. (2009). Glyphosate in the rhizosphere—role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants. *European Journal of Agronomy, 31*(3), 126–132.

Thiffault, N., & Roy, V. (2011). Living without herbicides in Québec (Canada): historical context, current strategy, research and challenges in forest vegetation management. *European Journal of Forest Research, 130*, 117–133. Retrieved from https://rd.springer.com/article/10.1007/s10342-010-0373-

Thompson, D., Leach, J., Noel, M., Odsen, S., & Mihajlovich, M. (2012). Aerial forest herbicide application: comparative assessment of risk mitigation strategies in Canada. *Forestry Chronicle, 88*(2), 176–184.

Thompson, D. G., & Pitt, D. G. (2011). *Frequently asked questions (FAQs) on the use of herbicides in Canadian forestry* (Frontline Technical Note 112). Canadian Forest Service, Great Lakes Forestry Centre.

Thompson, D. G., Pitt, D. G., Buscarini, T. M., Staznik, B., & Thomas, D. R. (2000). Comparative fate of glyphosate and triclopyr herbicides in the forest floor and mineral soil of an Acadian forest regeneration site. *Canadian Journal of Forest Research, 30*, 1808–1816.

Thompson, D. G., Pitt, D. G., Staznik, B., Payne, N. J., Jaipersaid, D., Lautenschlager, R. A., et al. (1997). On-target deposit and vertical distribution of aerially released herbicides. *Forestry Chronicle, 73*(1), 47–59.

Thompson, D. G, Wojtaszek, B. F., Staznik, B., Chartband, D. T., & Stephenson, R. (2004). Chemical and biomonitoring to assess potential acute effects of VisonR herbicide on native amphibian larvae in forest wetlands. *Environmental Toxicology and Chemistry, 23*, 843–849.

Vitousek, Peter & Andariese, Steven & Matson, Pamela & Morris, Lawrence & Sanford Jr, Robert. (1992). Effects of harvest intensity, site preparation, and herbicide use on soil nitrogen transformations in a young loblolly pine plantation. *Forest Ecology and Management*. 49. 277-292.

Wan, M. T. K. (1986). The persistence of glyphosate and its metabolite amino- methyl-phosphonic acid in somecoastal British Columbia streams. Regional Program Report 85-01. Dep. Environ., Environ. Prot. Serv., Vancouver, B.C

Wan, M. T., Watts, R. G. & Moul, D. J. (1989). Effects of different dilution water types on the acute toxicity to juvenile pacific salmonids and rainbow trout of glyphosate and its formulated products. *Bulletin of Environmental Contamination and Toxicology, 43*, 378–385. https://doi.org/10.1007/BF01701872

Wardle, D. A., & Parkinson, D. (1990). Influence of the herbicide glyphosate on soil microbial community structure. *Plant and Soil, 122*(1), 29–37.

Whitehead, R. J., & Harper, G. J. (1998). *A comparison of four treatments for weeding Engelmann spruce plantations in the Interior Cedar Hemlock Zone of British Columbia: ten years after treatment* (Information Report BC-X-379). Victoria, BC: Canadian Forest Service, Pacific Forestry Centre.

Wood, J. L. (2019). The presence of glyphosate in forest plants with different life strategies one year after application. *Canadian Journal of Forest Research, 49*(6), 586–594. https://doi.org/10.1139/cjfr-2018-0331

Wood, J. E., & von Althen, F. W. (1993). Establishment of white spruce and black spruce in boreal Ontario: effects of chemical site preparation and post-planting weed control. *Forestry Chronicle 69*, 554–560.

Zaller, J. G., Heigl, F., Ruess, L., & Grabmaier, A. (2014). Glyphosate herbicide affects belowground interactions between earthworms and symbiotic mycorrhizal fungi in a model ecosystem. *Scientific Reports, 4*, 5634.

APPENDIX 1. INTERNATIONAL ASSESSMENTS

Various international expert panels and regulators have reviewed glyphosate and its effect on human health. The consensus among national pesticide regulatory agencies and scientific organizations is that labelled uses of glyphosate have demonstrated no evidence of human carcinogenicity (Tarazona et al., 2017).

International Agency for Research on Cancer

In March 2015, the World Health Organization's International Agency for Research on Cancer (IARC), consisting of 17 experts from 11 countries, classified glyphosate as "probably carcinogenic in humans" based on epidemiological studies, animal studies, and in vitro studies.[9] This was based on "limited" evidence of cancer in humans (from exposures that actually occurred) and "sufficient" evidence of cancer in experimental animals (from studies of "pure" glyphosate). "Limited" evidence means that a positive association between exposure to the agent and cancer has been observed but that other explanations for the observations (called chance, bias, or confounding) could not be ruled out.

The International Agency for Research on Cancer also concluded that there was "strong" evidence for genotoxicity, both for "pure" glyphosate and for glyphosate formulations.[10]

European Food Safety Authority

In October 2015, the European Food Safety Authority of the European Union (EU) concluded that "the substance is unlikely to be genotoxic (i.e., damaging to DNA) or to pose a carcinogenic threat to humans."[11]

Glyphosate was not proposed to be classified as carcinogenic under the EU regulation for classification, labelling, and packaging of chemical substances. In particular, all the member state experts but one agreed that neither the epidemiological data (i.e., on humans) nor the evidence from animal studies demonstrated causality between exposure to glyphosate and the development of cancer in humans. A supplementary document clarified that while carcinogenic glyphosate-containing formulations may exist, studies "that look solely at the active substance glyphosate do not show this effect.[12]

Joint Food and Agriculture Organization of the United Nations/World Health Organization

The World Health Organization and Food and Agriculture Organization of the United Nations Joint Meeting on Pesticide Residues issued a report in 2016 stating that the use of glyphosate

9 https://www.iarc.fr/featured-news/media-centre-iarc-news-glyphosate/

10 https://monographs.iarc.fr/wp-content/uploads/2018/06/mono112-10.pdf

11 http://www.efsa.europa.eu/en/efsajournal/pub/4302

12 http://www.efsa.europa.eu/sites/default/files/4302_glyphosate_complementary.pdf

formulations does not necessarily constitute a health risk, and giving admissible daily maximum intake limits (1 mg/kg of body weight per day) for chronic toxicity.[13]

Environmental Protection Agency

In 2017, the U.S. Environmental Protection Agency classified glyphosate as "not likely to be carcinogenic to humans."[14] The Agency's assessment found no other meaningful risks to human health when the product is used according to the pesticide label.

European Chemicals Agency

In March 2017, the Committee for Risk Assessment of European Chemicals Agency concluded that the available scientific evidence did not meet the criteria to classify glyphosate as a carcinogen, as a mutagen, or as toxic for reproduction. However, it was classified as causing serious eye damage and being toxic to aquatic life, with long-lasting effects.[15]

Australian Pesticides and Veterinary Medicines Authority

In 2017, the Australian Pesticides and Veterinary Medicines Authority reviewed the IARC monograms and other international assessments and concluded that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.[16] The Agency provides a good online overview of various studies and issues, as well as an explanation of the IARC assessment.[17]

California

On July 7, 2017, in agreement with the IARC classification, California listed glyphosate as a known carcinogen under Proposition 65 law, which would require indicating this carcinogenicity hazard on the product label of glyphosate-based herbicide products. However, in response to a legal claim by an agricultural coalition that included the National Association of Wheat Growers, Monsanto Corporation, and farmer groups, the U.S. District Court issued a preliminary injunction against this evaluation on the basis that the classification by IARC claims glyphosate only probably carcinogenic, while apparently all other regulatory and governmental bodies found the opposite, including the U.S. Environmental Protection Agency.[18]

Canada

In 2015, Health Canada's Pest Management Regulatory Agency (PMRA) released a Proposed Re-evaluation Decision document on glyphosate. The consultation document described the registration process for the use of herbicides in Canada, a summary of the science evaluated, and the reasons for the proposed re-valuation decision. Input comments were solicited. The Agency re-evaluates pesticides on a recurring basis to ensure they meet modern health and environment safety standards and continue to have value. In April, 2017, Health Canada reapproved glyphosate. The Re-evaluation Decision document summarized the Agency's final decision on glyphosate, the reasons for it, and PMRA's response to comments received. An evaluation of the available scientific information found that products containing glyphosate do

13 https://www.who.int/foodsafety/areas_work/chemical-risks/JMPR_2016_Report_May.pdf

14 https://www.epa.gov/pesticides/epa-releases-draft-risk-assessments-glyphosate

15 https://echa.europa.eu/-/glyphosate-not-classified-as-a-carcinogen-by-echa

16 https://apvma.gov.au/sites/default/files/publication/26561-glyphosate-final-regulatory-position-report-final_0.pdf

17 https://apvma.gov.au/node/13891

18 https://www.frontiersin.org/articles/10.3389/fenvs.2018.00078/full

not present risks of concern to human health or the environment when used according to the revised label directions. As a requirement for the continued registration of glyphosate uses, new risk-reduction measures were required for end-use products registered in Canada. These included a restricted-entry period of 12 hours for agricultural uses, directions for application to minimize the potential for drift into areas of human activity, environmental hazard statements, spray buffer zones, precautionary statements, and use restrictions to reduce runoff into aquatic areas.

Following Health Canada's re-evaluation decision in 2017, eight notices of objection were received. There were also public concerns about the validity of the science as indicated in the so-called “Monsanto Papers”. On January 11, 2019, Health Canada issued a statement indicating that after a thorough scientific review, objections to glyphosate use could not be scientifically supported when considering the entire body of relevant data.

APPENDIX 2. STOCKING STANDARDS AND SURVEY CHANGES RELATED TO DECIDUOUS MANAGEMENT IN BRITISH COLUMBIA

2007: Recognizing the autecology of the competition species, specifically shrub and herb compared to broadleaf species (deciduous), and the effects of these specific competitors on managed coniferous stands.

2007: Using improved free-growing decision-making tools via the quadrant method to evaluate free growing and "potentially" free-growing trees at the plot level, considering:

• site series specific competition thresholds

• competition thresholds specific to the silvics of managed crop species

This is a more refined evaluation method in the Coast, North, and South regions compared to simply evaluating competition within a 1-m cylinder with standard crop-to-brush ratios, as used in the past.

2009: Employing regionally developed brush competition assessments, specific to many BEC variants in the three Cariboo Timber Supply Areas, based on empirical data collected by silviculture researchers. This neighbourhood concept has led to a greater flexibility in crop trees being assessed as free growing when intermixed and overtopped by broadleaf competition. As well, in certain BEC variants in the Cariboo, broad leaf competition is considered as "non-deleterious", which does not affect their status as free growing.

2011: Developing new broadleaf forest health free-growing damage criteria, used to assess the acceptability of broad-leaves as free growing, given these deciduous species are specified as crop trees in an approved Forest Stewardship Plan.

2018: Expanding the "non-deleterious" definition of broadleaf competition, in conifer managed stands, to all site series within the IDFdk4 and SBPSxc BEC variants within the three Cariboo Timber Supply Areas.

APPENDIX 3. INTEGRATED PEST MANAGEMENT PRINCIPLES

Elements of Integrated Pest Management include:

1. prevention;

2. pest identification;

3. seedling and vegetation monitoring;

4. injury thresholds and treatment decisions;

5. treatment options and selection criteria; and

6. post-treatment effectiveness evaluation.

Environmental protection strategies and procedures

Prevention

Prevention of vegetation competition issues can be achieved through the following:

- **Site preparation:** The intent of site preparation is to reduce the impacts of growth-limiting factors that might inhibit seedling establishment or growth potential.
- **Planting:** Stock with high genetic worth can improve survival performance of planted seedlings. Similarly, large seedling stock is better suited to compete for light and can withstand higher brush hazards.
- **Species selection:** Species selection is based on the ecological suitability of a species to the specific site conditions in an area. Additional considerations include immediate and long-term forest health factors, future forest products, volume and value, climate change, and consistency with the Timber Supply Analysis.
- **Regeneration delay:** Seedlings that are quickly established are more likely to compete successfully with problematic vegetation. Especially on brush-prone sites, seedlings should be planted as soon as possible following harvesting.
- **Microsite selection:** Seedlings that are planted in the best microsite possible and that remain undamaged during the planting process are more likely to compete successfully with problematic vegetation.
- **Fertilization:** Fertilization treatments can improve seedling establishment and reduce the need for brushing.
- **Advanced regeneration**: Another stand establishment option is to utilize advanced growth in the understory at the time of harvesting. This could involve partial cuts such as shelterwood silviculture systems where silvics and site conditions are appropriate.

Pest identification

In the context of vegetation management, the term "pest" refers to herbaceous, shrub, and broadleaf complexes or communities that:

- inhibit plantation establishment;
- hinder optimal growth and development of crop trees;
- prevent a stand from achieving free growing;
- affect an established plantation's overall health; or
- when combined with snow, causes damage to crop trees by snow press.

Identification of potential vegetation problems starts with sound ecosystem classification from which vegetation complexes can be predicted. Post-harvest assessments and seedling monitoring can also help in identifying potential or realized brush problems.

Seedling and vegetation monitoring

Surveys and walk-throughs are scheduled throughout the plantations' development in order to ensure that stocking and brush levels are acceptable and that free-growing parameters will be achieved within the appropriate time frame. Monitoring includes post-harvest assessments, regeneration delay surveys, regeneration performance walk-throughs, and free-growing surveys.

Injury thresholds and treatment decisions

Decisions to control vegetation on a site may be based on a number of different protocols depending on regional and ecological parameters. Measures such as competition index (CI) and height-to-diameter ratio may be used to determine whether competing vegetation is negatively impacting crop trees. Crop tree status and vigour may also be evaluated based on local knowledge or percentage of crop trees that are overtopped, threatened, or above the brush.

Competition index measures competition for sunlight with regards to crop trees. It is calculated as the sum of the products of cover and height for all non-crop species within a 1.26-m radius around a crop tree, divided by crop-seedling height, and shows that growth declines with increases in the index. There is a very rapid decline in growth as Cl increases from 0 to 100. At Cl = 100, growth is approximately 60% of that of a seedling growing free from competition. At a Cl = 150, seedlings receive 30% of the full sunlight in midsummer and would achieve approximately 45% of potential growth rates (Comeau et al., 1993). Treatment may be recommended when Cl > 80.

Height-to-diameter ratio (HDR) of crop trees can indicate sturdiness. In low light conditions, conifers will put more resources toward height growth, which makes them susceptible to vegetation and snow press. Treatment may be recommended with HDR > 40 or 50, depending on species, where > 50% of stems exceed the HDR.

Treatment options

Aerial application

Broadcast treatment using a helicopter equipped with a low-pressure boom and high-volume nozzles. Variable application rates are possible. May control brush for 2–4 years.

Discretionary, non-continuous application across portions of the block can also be applied.

The most cost-effective treatment and the safest option for workers on the ground

Benefits	Limitations
• Effective control for a number of years • Minimal worker contact with chemicals • Low cost • Can treat remote, steep, slashy ground more safely than alternatives • Can treat large areas in a short time	• Less selective than other methods • Stringent application constraints • Intensive preparation and follow-up • High public profile • Residual leave trees are obstacles • Visual quality affected for years • Technically demanding • Drift can occur outside treatment areas

Backpack application

Backpack broadcast—continuous application across treatment unit with low-pressure backpack sprayer with adjustable nozzles. Variable application rates are possible. May control brush for 2–4 years. Discretionary non-continuous or spot treatment can be applied.

Benefits	Limitations
• Effective control for a number of years • Can treat blocks with standing residuals • Selective. Can apply with precision • Only small buffers needed in pesticide-free zones	• Stringent application constraints • Intensive preparation and follow-up • Requires high level of supervision • Exposure of workers to herbicide • Safety concerns about wearing heavy equipment on rough terrain • Access and water availability • Constrained by brush height • Inconsistent results from dew, rainfall, and missed spots that are difficult to detect during monitoring • Safety concerns about evacuating from remote sites • Crew availability

Cut stump

Selective application of herbicide onto a cut stump of target vegetation. Brush saw or power saw cuts the stump, and a worker applies herbicide using a backpack sprayer, squeeze bottle, or nozzle mounted on the saw. May control brush for approximately 4 years.

Benefits	Limitations
• Effective control for a number of years • Longer treatment window • Little worker exposure to herbicide • Only small buffers needed in pesticide-free zones • Low application rate	• Stringent application constraints • Intensive preparation and follow-up • Requires high level of supervision • Some exposure of workers to herbicide • Safety hazards operating power saws • Safety concerns about wearing heavy equipment on rough terrain

Motor-manual

Workers cut target vegetation with power saws or brush saws. May control herbaceous brush for less than 1 year, deciduous brush for about 2 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatments
• Public acceptance	• Safety hazards operating power saws
• Can be applied selectively	• Expensive treatment cost
• Can be used in pesticide-free zone buffers	• Relatively short window for treatment
• Not effective on herbaceous brush	• Limited availability of workers
	• Slash loads can be fire hazards, limit trafficability

Hand tools

Workers treat spots around crop trees with handheld cutters.

Girdling hardwoods to remove a continuous strip of bark around the circumference, which kills trees 2–3 years later.

Snap/hinge—partially breaking smaller stems by hand.

May control brush for less than 1 year. Girdling can control brush for about 3 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatments
• Public acceptance	• Expensive treatment cost
• Can be applied selectively	• Repetitive strain injuries are common
• Can be used in pesticide-free zone buffers	• Limited availability of workers
	• Girdling not effective on herbaceous brush

Sheep grazing

Shepherds guide a flock of sheep (1000–1500) through treatment areas, where they eat target vegetation. May control brush for 1 year.

Benefits	Limitations
• No herbicide use	• Expensive treatment cost
• Not constrained by weather	• Some crop tree damage
• Safe for workers	• Herbaceous, limited height
	• Need good access, gentle terrain, low slash.

- Risk of disease to wildlife
- Risk from predators

Mechanical site preparation

Mechanically creating favourable planting spots that mitigate limiting site factors such as cold, poorly aerated soils, competing vegetation, and frost risk. Where brush hazards are high, mounding is preferred so seedlings are elevated and receive more light, and vegetation falls away from crop trees rather than presses over them. Mounding is done with excavators or implements attached to prime movers such as skidders. May control brush for 3–5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Public acceptance	• Access and soil disturbance
• Increased soil temperature	• Site constraints—trafficability
• Facilitates planting	• Availability of contractors in the north

Prescribed burning

Prescribed burning is another form of site preparation that uses ground crews or a helicopter to apply a controlled burn. May control brush for 3–5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Good seedbed, plantable spots	• Liability and risk of escape
	• Smoke and health effects
	• Risks to workers

Treatment selection

Treatment methods for a specific site will be selected based on a number of factors, including safety concerns, timing, treatment efficacy, cost, biophysical constraints, legal constraints, political constraints, and concerns from other users and stakeholders. The following lists some of these factors:

- **Target species height**: Backpack treatments cannot be sprayed overhead. Sheep are also constrained by their ability to reach foliage and are restricted to sites with vegetation less than 1 m in height.
- **Target species diameter**: Girdling is impractical at diameters of less than 3 cm or greater than 10 cm.
- **Target species distribution**: Broadcast foliar treatments are not effective if target species are in clumps. Discretionary treatments are less appropriate if the target brush is evenly distributed.
- **Physical impediments to treatment**: Aerial treatments can be limited by residual trees, or small, irregular shaped treatment units. Ground-based treatments can be affected by steep slopes, uneven terrain, slash loading, difficult access, and remote access.

- **Buffers**: Blocks with many features that require no-treatment zones and pesticide-free zones, such as water bodies, wetlands, and roads, may have little area for herbicide treatments once all the buffers are established.
- **Timing**: Chemical treatment windows are small and require conifers that are hardening off to avoid chemical damage while target species are still succulent. Motor-manual treatment windows may overlap with fire seasons and are dependent on fire risk safety measures.
- **Special wildlife features**: Heavy browsing might reduce the need for brushing if there is little alternative browse available. Treatments that create heavy slash loads that restrict game movement may be avoided. Sheep grazing may be a poor choice in grizzly bear high-use areas.
- **Vulnerable plant species**: Vulnerable plant species are defined as those plants whose numbers are either limited or are important for browse or forage. Vulnerable plant species must be protected from broadcast treatments where identified.
- **First Nations rights infringement**: When specific information indicates that there is a higher likelihood of treatments infringing on First Nations rights on a unit, certain treatments may be considered unsuitable, or modified. For example, if consultation with a First Nation indicated that a specific site is used for berry-picking, a broadcast chemical treatment would be considered inappropriate.
- **Potential for conflict**: Some proposed treatments may result in an unacceptable risk of conflict with the public, First Nations, or other stakeholders.
- **Potential for crop tree damage**: Heavy slash loading from motor-manual treatments could mechanically damage crop trees. It can be difficult to spot crop trees in dense vegetation, which can result crop tree damage. Brushing can increase the risk of root rot spreading. Slash loading or dead stems can also create fire risks.
- **Availability of crews**: It is increasingly difficult to attract workers to the silviculture industry, and brushing is onerous physical work. Safety is also a factor, as higher numbers of injury claims are associated with higher claim payments for brushing and weeding. Fewer people are engaging in this sector. The area manually brushed, 11,600 ha in 2018, would have to double to treat the sprayed area, so workforce availability would be limiting.

Post-treatment effectiveness evaluation

Efficacy is checked for the amount of target vegetation removed, current level of competition, missed areas, crop tree damage, environmental impacts, and scheduling of next entry.

Environmental protection strategies and procedures

Operational procedures and standards for herbicide applications (including herbicide transportation, storing, mixing, loading, disposal) and the environmental safeguards in place regarding herbicide field application, including considerations regarding:

- strategies to protect community watersheds and other domestic water sources
- strategies to protect fish and wildlife, riparian areas, and wildlife habitat
- pesticide-free zones
- species at risk

- strategies to prevent herbicide treatment of food intended for human consumption
- pre-treatment inspection procedures for identifying treatment area boundaries
- weather monitoring and strategies
- procedures for maintaining and calibrating herbicide application equipment

GLOSSARY

BEC	Biogeoclimatic Ecosystem Classification
FLNRORD	B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FPPR	Forest Planning and Practices Regulation
FSP	Forest Stewardship Plan
IPMR	Integrated Pest Management Regulation
PMP	Pest Management Plan
PMRA	Health Canada Pest Management Regulatory Agency
RESULTS	Reporting Silviculture Updates and Land Status Tracking System
sph	stems per hectare



info@fpinnovations.ca
www.fpinnovations.ca

OUR OFFICES

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
(514) 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
(604) 224-3221

Québec
1055 rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
(418) 659-2647

BRIEFING NOTE FOR INFORMATION

DATE:	December 16, 2019
PREPARED FOR:	Honourable Doug Donaldson, Minister of Forests, Lands, Natural Resource Operations and Rural Development
ISSUE:	FPInnovations' Glyphosate Use in BC Forestry, Review Report

BACKGROUND:

- Glyphosate is an herbicide used by forest managers to reduce broadleaf competition of conifer plantations to assist achievement of free-to-grow status.
- Glyphosate use is a controversial issue with the public, particularly related to recent claims of habitat impacts and the decline in moose populations.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee comprised of staff from Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) and Environment and Climate Change (ENV) was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was contracted to assess current peer reviewed forest science and best practices related to glyphosate use primarily in the context of the current value-set that applies to forest management throughout BC (e.g., biodiversity, First Nations, climate change, soil and water, etc.).
- This note provides a brief summary of FPI's report and sets out next steps, including internal and external communication.

DISCUSSION:

- Based on an initial assessment of the ~50-page report (ref. Appendix 1), FPI reports that the risk of glyphosate and its metabolites[1] on the environment is minimal when the herbicide is applied according to the product instructions (label). Further, it confirms that species richness and diversity of flora and fauna remain in the range of natural variation, and that any changes to these communities when glyphosate is used is transient.
- Glyphosate is one of many vegetation management tools available to forest managers. Glyphosate, while very cost-effective, is declining in use relative to the forested area harvested each year. In 2018, ~ 11,000 hectares of Crown land in BC were treated with glyphosate representing 7 percent of the Crown area harvested that year, most of which was in the Omineca Forest Region.
- Further, the FPI report also indicates that contrary to current public perceptions, the data indicates that parts of BC have shown a significant increase in mixed deciduous stands over the years due to previous harvesting activity; even in stands that have been previously treated with glyphosate. Deciduous trees still account for 15-20 percent of the stems per hectare at free growing.

[1] A metabolite refers to the product that remains after a chemical has broken down, digested or otherwise processed.

- The FPI report also makes a series of recommendations related to opportunities to improve research and data; particularly with respect to glyphosate persistence in plants, impact on soil micro-organisms, wildlife forage and fire behaviour.
- The FPI report also includes recommendations related to the opportunities to improve two-way communication with First Nations and the public related to glyphosate use.

NEXT STEPS:

s.13

Attachments:

1. Briefing note "*Summary of FPInnovations Glyphosate Review Report*" (CLIFF 252256).
2. Review of Glyphosate Use in BC Forestry (FPI, Dec. 11, 2019).

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
MO		
DMO		
ADM	DN	December 19, 2019
ED	SB	December 16, 2019
Program Dir/Mgr.	SH	December 13, 2019

BRIEFING NOTE FOR INFORMATION

DATE:	December 12, 2019
PREPARED FOR:	Diane Nicholls, Assistant Deputy Minister, Chief Forester, Minister of Forests, Lands, Natural Resource Operations and Rural Development
ISSUE:	Summary of FPInnovations Glyphosate Review Report

BACKGROUND:

- Glyphosate is an herbicide used by the forest sector to reduce broadleaf competition with conifer plantations in order to assist in the achievement of free-to-grow status.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was awarded a $75,000[1] consulting services contract to assess current peer-reviewed forest science and best practices related to glyphosate use in the context of, but not necessarily limited to:
    - The current value-set that applies to forest management throughout BC;
    - Where and why forest managers use glyphosate, how it relates to the current value-set e.g., carbon, First Nations (FN), wildlife, and wildlife habitat, and alternative vegetation management approaches;
    - Document the uncertainties and assumptions related to forestry-related glyphosate use; and
    - How glyphosate use supports the overarching objective of promoting the establishment of healthy and diverse forests.
- This note provides a summary of highlights, key findings and recommendations set out in FPI's report. Subsequent notes will address potential next steps, including internal and external communication.

HIGHLIGHTS, KEY FINDINGS AND RECOMMENDATIONS:

<u>General/Background</u>

- Glyphosate-based herbicides are the most widely used in the world due to their cost, effectiveness, and safety.
- The effects of glyphosate on human health have been extensively reviewed by international regulatory agencies, including Health Canada, with the conclusion generally being that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.
- Several factors can be considered to inform the use of glyphosate in forestry applications in BC, including:
    - Effective and targeted vegetation control to achieve plantation survival and achievement of the free growing objective (i.e., sustainable timber supply);

[1] Subsequently increased to $82,500.

- Cost-effectiveness relative to alternative treatment options;
- Ability to control resprouting of perennial competitive vegetation;
- Persistence in the natural environment through time (NB. biodegradation profile appears to vary in different ecosystem types);
- Toxicity to non-target flora and fauna in surrounding environment; and
- Potential trade-offs across non-timber objectives.

Regulation and Use

- Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada. The PRMA re-approved glyphosate for use in Canada in 2017. After objections were raised regarding the re-approval, the PRMA issued a supplementary statement in which it concluded that the objections could not be scientifically supported.
- The BC Ministry of Environment and Climate Change (ENV) regulates the sale and use of pesticides in BC under the *Integrated Pest Management Act*. Large scale use of pesticides requires the proponent to prepare and adhere to a Pest Management Plan.
- Notwithstanding its effectiveness as a silvicultural tool, glyphosate is also used to help manage invasive species. Of the 1,593 hectares treated with herbicides for control of invasive species under the BC provincial jurisdictions of highways, forests, and parks agencies in 2018, 8 percent of the area was treated using glyphosate.
- Data from this ministry's RESULTS application program shows that:
  - Roughly 11,000 hectares of Crown land was treated with glyphosate in 2018 with 86 percent sprayed aerially and 14 percent sprayed via ground-based methods;
  - Most of the spraying of glyphosate occurred in the Omineca Natural Resource Region (73 percent) followed by the Northeast Region (11 percent); and
  - Smaller amounts of glyphosate use also occurred in the Thompson-Okanagan and South Coast Regions.
  - The reasons for the high use of aerial application in the Omineca Region were not explicitly reviewed.
- The area sprayed has declined from an average of 13,802 hectares for the last five years and higher historical levels. The area sprayed in 2018 was 0.044 percent of the 25 million hectares available for harvesting in BC, and 0.44 percent of the tenured area on Crown land that has an outstanding reforestation obligation.
- The proportion of area harvested that has had any kind of vegetation control treatment has decreased from 18 percent to 14 percent over the last 10 years.
- In contrast to agriculture and other common land uses where areas are sprayed repeatedly, glyphosate in forestry is typically applied once or occasionally twice in a rotation.
- Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species, but are most commonly used in the Sub-Boreal Spruce biogeoclimatic zone targeting trembling aspen, mixed shrub, fireweed, and wet alder.

Treatment Costs

- Glyphosate treatment costs vary widely but are typically at least half that of manual methods (e.g., $300-$500/hectare vs. $700-$1,200/hectare). The differential cost of using manual methods vs. glyphosate for silviculture is currently estimated to $15 million/year based upon 11,000 hectares treated provincially exclusive of timber productivity losses.

Biodiversity

- One of the primary public concerns regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broadleaves are being eliminated from the landscape. These claims are not supported when analysing the level of deciduous components at free-growing, or the increase in mixed deciduous stands over time as a result of forest management.
- A 2008 review of species diversity pre- and post-harvest in BC found that the amount of deciduous mixed stands at free growing increased from 2,811 hectares before harvest to 55,614 hectares in the Northern Interior Forest Region for all reporting periods. Similarly, in the Southern Interior Forest Region, deciduous mixed stands increased from 1,202 hectares before harvest to 37,268 hectares at free growing, a 3,000 percent increase. Analysis further suggests that aspen stocking recovers after glyphosate spraying and may in fact be increasing over time with forest management activities.
- Studies found that species richness and diversity of non-target vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies also found that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment. In many cases, herbaceous vegetation abundance, diversity, and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank. Further, while glyphosate tends to result in a larger initial reduction of a wider range of species, brushing alternatives such as manual brushing has similar effects on plant communities, albeit at a higher treatment cost.
- Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions due to the phytotoxicity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least one year. Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality; however, some translocation into shoots and fruit was observed in select plants.

Aquatic Organisms

- Amphibian populations are declining around the world and chemical contaminants released to aquatic environments have been listed as a threat. Studies have shown direct effects of chronic glyphosate exposures on fish, amphibians, invertebrates, and other components of the ecosystem. However, field studies have not been able to replicate these toxicity effects under typical glyphosate application rates and conditions. Further, numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development, the expression of genes related to larval development, or juvenile amphibian survival. This is likely due to the short exposure duration and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands.
- A field study in coastal BC found temporary stress effects and minor mortality in caged Coho salmon smolt post glyphosate application. However, no acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident Coho.

Similarly, no effects on growth, behaviour, or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment. While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations in BC mandate the use of no-treatment pesticide-free zones around water features, dry streams, and classified wetlands, further reducing the risk of negative effects on aquatic ecosystems.

Wildlife

- Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates. However, some uncertainty remains regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage.
- Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline.
- Glyphosate treatment has been found to reduce wildlife forage availability in the short term, reducing moose use of glyphosate-treated area for the first few years after treatment. However, the long-term impact of glyphosate use on habitat selection by moose is not well understood. Further, some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls, although these impacts must also be considered in relation to the area treated annually and its distribution over the landscape. The effects of glyphosate's chelating[2] properties on forage quality and nutrient availability are also poorly understood.

Soil and Water Quality

- Glyphosate is largely immobilized in the soil and then dissipates via microbial degradation. One of the compounds released during the microbial breakdown process – AMPA – is adsorbed to soils and biodegraded. However, AMPA is considered to be a mild phytotoxin with relatively unknown long-term consequences on soil organisms and plants.
- The mandated use of no-treatment pesticide-free zones around water features, the strong sorption to upper soil layers, and the rapid uptake by plants minimize the risk of glyphosate entering aquatic ecosystems. Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken.

Climate Change

- Vegetation management can affect carbon sequestration due to its impact on structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows the establishment of a woody crop, delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools. When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species.

[2] Chelation is a type of bonding of ions and molecules to metal ions. It involves the formation or presence of two or more separate coordinate bonds between a polydentate ligand and a single central atom. These ligands are called chelants, chelators, chelating agents, or sequestering agents.

Wildfire

- Fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires.
- The Canadian Forest Fire Behaviour Prediction system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous or leaf-on mixed wood stands.
- Amongst deciduous trees, poplars show the most fire resistance. In one study, researchers estimate broadleaf forests to remain next to inflammable even as drought conditions worsen, in stark contrast to coniferous forests.
- The effect of fire behaviour from deciduous vegetation treated with glyphosate is not well documented. It is expected that the fire hazard in treated dead stems following treatment either manually or chemically would be very high.

First Nations

- Some FNs across BC have expressed concern over the use of glyphosate in forests related to plants that are traditionally gathered for food or medicinal purposes, and which are killed directly by glyphosate or are considered contaminated.

Public Use

- Forest managers are faced with mounting public pressure over the safety of glyphosate use.
- Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping or hiking. The PMRA's review on glyphosate has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health.
- There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues.
- Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue.
- Better communication of the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, between forest managers and recreational users, can help address key public concerns.

Timber Supply

- Vegetation control in some cases is necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term, and the economic benefit derived from forests.
- Glyphosate is cost-effective vs. manual vegetation control methods.
- Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked area with

direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

Conclusions

- Glyphosate is one of a number of vegetation management tools available to forest managers and is the most cost-effective way to manage competing vegetation to promote plantation survival, meet free growing obligations to ensure stand productivity and a sustainable timber supply into the future.
- A review of current inventory data shows that stands that have been treated with glyphosate retain 15-21 percent deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.
- Field studies have shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds, and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.
- Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.
- While more research is recommended on the identified knowledge gaps, the use of glyphosate needs to be further considered within the context of the amount of area treated, the short time scale of site-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels. Many of the public's concerns and challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by better linkages between site and landscape level planning that allow other non-timber values to be prioritized where needed.

Recommendations

s.13

s.13

Attachments: Review of Glyphosate Use in BC Forestry (FPI, Dec. 11, 2019).

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
ADM	DN	December 19, 2019
ED	SB	December 16, 2019
Program Dir/Mgr.	SH	December 12, 2019

From:	FLNR eApprovals
To:	Silverio, Lisa FLNR:EX; Purdy, Sandra FLNR:EX; Jones, Tristan FLNR:EX
Subject:	NOTIFICATION - eApprovals Item ID: 4173 - Item Forwarded - - Due 12/24/2019
Date:	Monday, December 23, 2019 10:02:05 AM

Purdy, Sandra FLNR:EX [Assignee] forwarded an eApprovals item to Donaldson, Doug for action

Comment: Glyphosate Review Report and Info Note for your review.

#: 252744

Title: 252744 BNI MIN FPInnovations Glyphosate Review Report XREF 252256

Full Name:

Due Date: 12/24/2019

Category: Briefing Note - Information Note

Go to item...

Ministry of
Forests, Lands and
Natural Resource Operations

Consulting and General Services Contract

CONTRACT./FILE NO:	THIS AGREEMENT DATED FOR REFERENCE THE
1070-20/FH20FHQ067	**27th day of May, 2019.**
PROJECT DESCRIPTION: GLYPHOSATE POLICY REVIEW	

BETWEEN:

HER MAJESTY THE QUEEN IN RIGHT OF THE PROVINCE OF BRITISH COLUMBIA, as represented by the MINISTER OF FORESTS, LANDS AND NATURAL RESOURCE OPERATIONS

ADM'S OFFICE
Office of the Chief Forester
3rd floor, 727 Fisgard Street
Victoria, BC V8W 9C2
Phone Number: (778) 974-5675
Ministry Representative: Shawn Hedges
E-mail Address: Shawn.Hedges@gov.bc.ca

(the "Province", "we", "us", or "our" as applicable)

AND:

FP Innovations
2665 East Mall
Vancouver, BC V6T 1W5
Phone Number: (604) 222-5618
E-mail Address: james.hunt@fpinnovations.ca
Contractor Representative: James Hunt
Business Number: A0071162 Extraprovincial company
WorkSafe BC and/or Personal Optional Protection Number: 795598 AA(001)

(the "Contractor", "you", or "your" as applicable)

The Province wishes to retain the Contractor to provide the Services specified in Schedule A and, in consideration for the remuneration set out in Schedule B, the Contractor has agreed to provide those Services, on the terms and conditions set out in this Agreement.

The Province and the Contractor agree as follows:

ARTICLE 1 DEFINITIONS

1.01 In this Agreement, unless the context otherwise requires:

(a) **"Business Day"** means a day, other than a Saturday or Sunday, on which Provincial government offices are open for normal business in British Columbia;

(b) **"Incorporated Material"** means any material in existence prior to the start of the Term or developed independently of this Agreement, and that is incorporated or embedded in the Produced Material by the Contractor or a Subcontractor;

(c) **"Material"** means the Produced Material and the Received Material;

(d) **"Produced Material"** means records, software and other material, whether complete or not, that, as a result of this Agreement, are produced by the Contractor or a Subcontractor and includes the Incorporated Material;

(e) **"Received Material"** means records, software and other material, whether complete or not, that, as a result of this Agreement, are received by the Contractor or a Subcontractor from the Province or any other person;

(f) **"Record"** is the definition of "record" in the *Interpretation Act* and as incorporated into this Agreement and "records" will bear a corresponding meaning;

(g) **"Services"** means the services described in Schedule A;

(h) **"Subcontractor"** means a person described in Section 16.05;

(i) **"Term"** means the term of the Agreement described in Section 3.01 of this Agreement subject to that term ending earlier in accordance with this Agreement; and

(j) **"Unit of Measure"** has the meaning described in Schedule B.

ARTICLE 2 CONTRACT DOCUMENTS AND MODIFICATIONS

2.01 The attached schedules are applicable to and form part of this Agreement:

Schedule	Title
Schedule 'A'	Services
Schedule 'B'	Payment
Schedule 'C'	Safety
Schedule 'D'	Insurance

2.02 No modification of this Agreement is effective unless it is in writing and signed by, or on behalf of, the parties.

ARTICLE 3 TERM OF CONTRACT

3.01 The Term of this Agreement is from and including **the 30th day of May, 2019** to and including the **31st day of December, 2019** inclusive.

3.02 Regardless of the date of execution or delivery of this Agreement, the Contractor must provide the Services during the Term.

3.03 Time is of the essence in this Agreement and, without limitation, will remain of the essence after any modification or extension of this Agreement, whether or not expressly restated in the document effecting the modification or extension.

ARTICLE 4 CONTRACTOR'S OBLIGATIONS

4.01 You must provide the Services described in Schedule A (the "Services") in accordance with this Agreement.

4.02 Unless the parties otherwise agree in writing, you must supply and pay for all labour, materials, equipment, tools, facilities, and approvals and licences necessary or advisable to perform your obligations under this Agreement, including the license under Section 8.04.

4.03 Unless otherwise specified in this Agreement, you must perform the Services to a standard of care, skill, and diligence maintained by persons providing, on a commercial basis, services similar to the Services.

4.04 You must provide, instruct, and supervise a sufficient number of qualified personnel to enable timely and proper performance and completion of the Services. All such personnel shall be competent, English literate, efficient and qualified by education, training and experience to carry out the tasks to which each is assigned.

4.05 We may from time to time give you reasonable instructions (in writing or otherwise) as to the performance of the Services. You must comply with those instructions but, unless otherwise specified in this Agreement, you may determine the manner in which the instructions are carried out.

4.06 If we provide an instruction under Section 4.05 other than in writing, you may request that the instruction be confirmed by us in writing, which request we must comply with as soon as it is reasonably practicable to do so.

4.07 Requesting written confirmation of an instruction under Section 4.06 does not relieve you from complying with the instruction at the time the instruction was given.

4.08 In the performance of your obligations under this Agreement, you must comply with all applicable laws.

ARTICLE 5 PAYMENT

5.01 If you comply with this Agreement, we must pay you at the rates and times described in Schedule B:

(a) the fees described in that Schedule;

(b) the expenses, if any, in accordance with that Schedule if they are supported, where applicable, by proper receipts and, in our opinion, are necessarily incurred by you in providing the Services; and

(c) any applicable taxes payable by us under law or agreement with the relevant taxation authorities on the fees and expenses described in paragraphs (a) and (b).

We are not obliged to pay you more than the maximum amount or dollar limit specified in Schedule B on account of fees and expenses.

5.02 In order to obtain payment of any fees or expenses, if any, under this Agreement, you must submit written statements of account to us in a form satisfactory to us, but no sooner than the dates referred to in Schedule B.

5.03 Without limiting Section 11.01 we may withhold from any payment due to you an amount sufficient to indemnify, in whole or in part, the Province and its employees and agents against any liens or other third-party claims that have arisen or could arise in connection with the provision of the Services. An amount withheld under this section must be promptly paid by the Province to you upon the basis for withholding the amount having been fully resolved to the satisfaction of the Province.

5.04 Our obligation to pay money to you is subject to the *Financial Administration Act*, which makes that obligation subject to an appropriation being available in the fiscal year of the Province during which payment becomes due.

5.05 Unless otherwise specified in this Agreement, all references to money are to Canadian dollars.

5.06 If you are not a resident in Canada, you acknowledge that we may be required by law to withhold income tax from the fees described in Schedule B and then to remit that tax to the Receiver General of Canada on your behalf.

5.07 Without limiting Section 16.11(a), you must not, in relation to performing your obligations under this Agreement, commit or purport to commit us to pay any money except as may be expressly provided for in this Agreement.

5.08 You must:

(a) apply for, and use reasonable efforts to obtain, any available refund, credit, rebate or remission of federal, provincial or other tax or duty imposed on you as a result of this Agreement that the Province has paid or reimbursed to you or agreed to pay or reimburse to you under this Agreement; and

(b) immediately on receiving, or being credited with, any amount applied for under paragraph (a) remit that amount to us.

ARTICLE 6 REPRESENTATIONS AND WARRANTIES

6.01 As at the date this Agreement is executed and delivered by, or on behalf of, the parties, you represent and warrant to us as follows:

(a) except to the extent you have previously disclosed otherwise in writing to us:

(i) all information, statements, documents and reports furnished or submitted by you to us in connection with this Agreement (including as part of any competitive process resulting in this Agreement being entered into) are in all material respects true and correct,

(ii) you have sufficient trained staff, facilities, materials, appropriate equipment and approved subcontractual agreements in place and available to enable you to fully perform the Services, and

(iii) you hold all permits, licenses, approvals and statutory authorities issued by any government or government agency that are necessary for the performance of your obligations under this Agreement; and

(b) if the Contractor is not an individual:

(i) you have the power and capacity to enter into this Agreement and to observe, perform and comply with the terms of this Agreement and all necessary corporate or other proceedings have been taken and done to authorize the execution and delivery of this Agreement by, or on behalf of, you, and

(ii) this Agreement has been legally and properly executed by, or on behalf of, you and is legally binding upon and enforceable against you in accordance with its terms except as enforcement may be limited by bankruptcy, insolvency or other laws affecting the rights of creditors generally and except that equitable remedies may be granted only in the discretion of a court of competent jurisdiction.

ARTICLE 7 PRIVACY, SECURITY AND CONFIDENTIALITY

7.01 You must comply with the Privacy Protection Schedule if attached to this Agreement.

7.02 You must make reasonable security arrangements to protect the Material from unauthorized access, collection, use, disclosure, alteration, or disposal and comply with the Security Schedule, if attached.

7.03 You must treat as confidential all information in the Material and all other information accessed or obtained by you or a Subcontractor (whether verbally, electronically or otherwise) as a result of this Agreement, and not permit its disclosure or use without our prior written consent except:

(a) as required to perform your obligations under this Agreement or to comply with applicable laws;

(b) if it is information that is generally known to the public other than as a result of a breach of this Agreement; or

(c) if it is information in any Incorporated Material.

7.04 Any public announcement relating to this Agreement will be arranged by us and, if such consultation is reasonably practicable, after consultation with you.

7.05 You must not, without our prior written approval, refer for promotional purposes to the Province being your customer or the Province having entered into this Agreement.

ARTICLE 8 MATERIAL AND INTELLECTUAL PROPERTY

8.01 If you receive a request for access to any of the Material from a person other than us, and this Agreement does not require or authorize you to provide that access, you must promptly advise the person to make the request to us.

8.02 We exclusively own all property rights in the Material that are not intellectual property rights. Any equipment property we may provide to you or a subcontractor is our exclusive property. You must deliver any Material or equipment property to us immediately following expiration of this Agreement, or sooner upon our request, in the same condition it was supplied to you, excepting always loss or damage attributable to reasonable wear or tear.

8.03 We exclusively own all intellectual property rights, including copyright:

(a) in Received Material that you receive from us, and

(b) in Produced Material, other than any Incorporated Material.

Upon our request, you must deliver to us documents satisfactory to us that irrevocably waive in our favour any moral rights that you (or your employees) or a Subcontractor (or its employees) may have in the Produced Material and confirm the vesting in the Province of the copyright in the Produced Material, other than any Incorporated Material.

8.04 Upon any Incorporated Material being embedded or incorporated in the Produced Material and to the extent that it remains so embedded or incorporated, you grant us:

(a) a non-exclusive, perpetual, irrevocable, royalty-free, worldwide license to use, reproduce, modify, and distribute that Incorporated Material; and

(b) the right to sublicense to third-parties the right to use, reproduce, modify and distribute that Incorporated Material.

ARTICLE 9 RECORDS AND REPORTS

9.01 You must, upon our request, fully inform us of all work done by you or a Subcontractor in connection with providing the Services.

9.02 If Schedule B provides for you to be paid fees at a Unit of Measure rate or for you to be paid or reimbursed for expenses, you must maintain time records and books of account, invoices, receipts and vouchers of expenses in support of those payments, in form and content satisfactory to us. Unless otherwise specified in this Agreement, the Contractor must retain such documents for a period of not less than seven years after this Agreement ends.

ARTICLE 10 AUDIT

10.01 In addition to any other rights of inspection the Province may have under statute or otherwise, we may at any reasonable time and on reasonable notice to you, enter on your premises to inspect and, at our discretion, copy any of the Material and you must permit, and provide reasonable assistance to, the exercise by us of our rights under this section.

ARTICLE 11 INDEMNITY AND INSURANCE

11.01 You must indemnify and save harmless the Province and its employees and agents from any losses, claims, damages, actions, causes of action, costs and expenses that the Province or any of its employees or agents may sustain, incur, suffer or be put to at any time either before or after this Agreement ends, including any claim of infringement of third-party intellectual property rights, where the same or any of them are based upon, arise out of or occur, directly or indirectly, by reason of any act or omission by you or your agents, employees, officers, directors or Subcontractors in connection with this Agreement (each a "Loss"), excepting always liability arising out of the independent acts or omissions of the Province and its employees and agents.

11.02 You must comply with the insurance requirements in Schedule D, if attached, as those terms may be modified from time to time in accordance with our directions.

11.03 Without limiting the generality of Section 4.08, you must comply with, and must ensure that any Subcontractors comply with, all applicable occupational health and safety laws in relation to the performance of your obligations under this Agreement, including the *Workers Compensation Act* in British Columbia or similar laws in other jurisdictions.

11.04 At your own expense, and where required under *Workers Compensation Act* in British Columbia, you must obtain WorkSafe BC coverage for yourself, all workers and any shareholders, directors, partners or other individuals employed or engaged in the performance of the Services and you shall ensure all approved Subcontractors obtain WorkSafe BC Coverage.

11.05 If you are an individual or a partnership of individuals and do not have the benefit of mandatory workers compensation coverage under the *Workers Compensation Act* in British Columbia, you must apply for and maintain Personal Optional Protection under the *Workers Compensation Act*.

11.06 You are responsible for all fines, levies, penalties and assessments made or imposed under the *Workers Compensation Act* and regulations relating in any way to the Services.

11.07 Upon our request you must provide us with evidence of your compliance with Sections 11.02, 11.04 and 11.05.

ARTICLE 12 FORCE MAJEURE

12.01 An "Event of Force Majeure" means a natural disaster, fire, flood, storm, epidemic or power failure, war (declared and undeclared), insurrection or act of terrorism or piracy, strike (including illegal work stoppage or slowdown) or lockout, or a freight embargo if such event prevents a party from performing its obligations in accordance with this Agreement and is beyond the reasonable control of that party.

12.02 An "Affected Party" means a party prevented from performing its obligations in accordance with this Agreement by an Event of Force Majeure.

12.03 An Affected Party is not liable to the other party for any failure or delay in the performance of the Affected Party's obligations under this Agreement resulting from an Event of Force Majeure and any time periods for the performance of such obligations are automatically extended for the duration of the Event of Force Majeure provided that the Affected Party complies with the requirements of Section 12.04.

12.04 An Affected Party must promptly notify the other party in writing upon the occurrence of the Event of Force Majeure and make all reasonable efforts to prevent, control or limit the effect of the Event of Force Majeure so as to resume compliance with the Affected Party's obligations under this Agreement as soon as possible.

ARTICLE 13 NON-COMPLIANCE WITH AGREEMENT CONDITIONS

13.01 An "Event of Default" means any of the following:

(a) your failure to perform any of your obligations under this Agreement, or

(b) any representation or warranty made by you in this Agreement is untrue or incorrect, or

(c) an Insolvency Event, which means any of the following;

(i) an order is made, a resolution is passed or a petition is filed, for your liquidation or winding up,

(ii) you commit an act of bankruptcy, make an assignment for the benefit of your creditors or otherwise acknowledge your insolvency,

(iii) a bankruptcy petition is filed or presented against you or a proposal under the *Bankruptcy and Insolvency Act* (Canada) is made by you,

(iv) a compromise or arrangement is proposed in respect of you under the *Companies' Creditors Arrangement Act* (Canada),

(v) a receiver or receiver-manager is appointed for any of your property, or

(vi) you cease, in our reasonable opinion, to carry on business as a going concern.

13.02 On the happening of an Event of Default, or at any time thereafter, we may, at our option, elect to do any one or more of the following:

(a) by written notice to you, require that the Event of Default be remedied within a time period specified in the notice;

(b) pursue any remedy or take any other action available to us at law or in equity; or

(c) by written notice to you, terminate this Agreement with immediate effect or on a future date specified in the notice, subject to the expiration of any time period specified under Section 13.02(a).

13.03 No failure or delay on our part to exercise our rights in relation to an Event of Default will constitute a waiver by us of such rights.

13.04 If you become aware that an Event of Default has occurred or anticipates that an Event of Default is likely to occur, you must promptly notify us of the particulars of the Event of Default or anticipated Event of Default. A notice under this section as to the occurrence of an Event of Default must also specify the steps you propose to take to address, or prevent recurrence of, the Event of Default. A notice under this section as to an anticipated Event of Default must specify the steps you propose to take to prevent the occurrence of the anticipated Event of Default.

ARTICLE 14 TERMINATION

14.01 In addition to our right to terminate this Agreement under Section 13.02(c) on the happening of an Event of Default, we may terminate this Agreement for any reason by giving at least 5 days' written notice of termination to you.

14.02 Unless Schedule B otherwise provides, if we terminate this Agreement under Section 14.01:

(a) we must, within 30 days of such termination, pay you any unpaid portion of the fees and expenses described in Schedule B which corresponds with the portion of the Services that was completed to our satisfaction before termination of this Agreement; and

(b) you must, within 30 days of such termination, repay to us any paid portion of the fees and expenses described in Schedule B which corresponds with the portion of the Services that we have notified you in writing was not completed to our satisfaction before termination of this Agreement.

14.03 The payment by us of the amount described in Section 14.02(a) discharges us from all liability to make payments to the Contractor under this Agreement.

ARTICLE 15 DISPUTE RESOLUTION

15.01 In the event of any dispute between the parties arising out of or in connection with this Agreement, the following dispute resolution process will apply unless the parties otherwise agree in writing:

(a) the parties must initially attempt to resolve the dispute through collaborative negotiation;

(b) if the dispute is not resolved through collaborative negotiation within 15 Business Days of the dispute arising, the parties must then attempt to resolve the dispute through mediation under the rules of the British Columbia Mediator Roster Society; and

(c) if the dispute is not resolved through mediation within 30 Business Days of the commencement of mediation, the dispute must be referred to and finally resolved by arbitration under the *Arbitration Act*.

15.02 Unless the parties otherwise agree in writing, an arbitration or mediation under Section 15.01 will be held in Victoria, British Columbia.

15.03 Unless the parties otherwise agree in writing or, in the case of an arbitration, the arbitrator otherwise orders, the parties must share equally the costs of a mediation or arbitration under Section 15.01 other than those costs relating to the production of expert evidence or representation by counsel.

ARTICLE 16 GENERAL

16.01 Any notice or document contemplated by this Agreement, to be effective, must be in writing and delivered as follows:

(a) hand delivered to the party or the specified party representative, in which case it will be deemed to be received on the day of its delivery; or

(b) by prepaid post to the party's address specified on the first page of this Agreement, in which case if mailed during any period when normal postal services prevail, it will be deemed to be received on the fifth Business Day after its mailing; or

(c) delivered by courier service to the party's address specified on the first page of this Agreement, in which case it will be deemed received on the fifth Business Day after collection by the courier service; or

(d) by facsimile or electronic transmission to the specified facsimile number or Email address on the first page of this Agreement, in which case it will be deemed to be received on the day of transmittal unless transmitted after the normal business hours of the addressee or on a day that is not a Business Day, in which cases it will be deemed to be received on the next following Business Day.

16.02 Either party may from time to time give notice to the other party of a substitute address, Email address, or fax number, which from the date such notice is given will supersede for purposes of Section 16.01 any previous address, Email address, or fax number specified for the party giving the notice.

16.03 You must not assign your rights under this Agreement without our prior written consent.

16.04 You must not subcontract any of your obligations under this Agreement without our prior written consent, excepting persons listed in Schedule A.

16.05 No subcontract, whether consented to or not, relieves you from any obligations under this Agreement. You must comply with the Subcontracting Schedule if attached to this Agreement. You must ensure that any person retained by you or any person retained by a person retained by you fully complies with this Agreement in performing the subcontracted obligations.

16.06 We may, for reasonable cause, object to the use of a proposed Subcontractor and require you to retain another qualified subcontractor.

16.07 A waiver of any term or breach of this Agreement is effective only if it is in writing and signed by, or on behalf of, the waiving party and is not a waiver of any other term or breach.

16.08 This Agreement and any modification of it constitute the entire Agreement between the parties as to performance of the Services.

16.09 Sections 4.08, 5.01 to 5.04, 5.07, 5.08, 7.01 to 7.05, 8.01 to 8.04, 9.01, 9.02, 10.01, 11.01, 11.02, 11.07, 12.01 to 12.04, 13.02, 13.03, 14.02, 14.03, 15.01 to 15.03, 16.01, 16.02, 16.09, and 16.11, any accrued but unpaid payment obligations, and any other sections of this Agreement (including schedules) which, by their terms or nature, are intended to survive the completion of the Services or termination of this Agreement, will continue in force indefinitely, even after this Agreement ends.

16.10 The schedules to this Agreement (including any appendices or other documents attached to, or incorporated by reference into, those schedules) are part of this Agreement.

16.11 In relation to the performance of your obligations under this Agreement, you are an independent contractor and not our:

(a) employee or partner; or

(b) agent except as may be expressly provided for in this Agreement.

You must not act or purport to act contrary to this section.

16.12 You must not do anything that would result in personnel hired or used by you or a Subcontractor in relation to providing the Services being considered our employees.

16.13 If one or more individuals are identified in the schedules as "Key Personnel", you must cause those individuals to perform the Services on your behalf and not remove or replace them, without our prior written approval. Any approved replacement is at your expense.

16.14 We must make available to you all information in our possession which we consider pertinent to the performance of the Services.

16.15 You must not provide any services to any person in circumstances which, in our reasonable opinion, could give rise to a conflict of interest between your duties to that person and your duties to us under this Agreement.

16.16 If there is a conflict among provisions of this Agreement, a provision in the body of this Agreement will prevail over any conflicting provision in, attached to, or incorporated by reference into a schedule, unless that conflicting

provision expressly states otherwise and a provision in a schedule will prevail over any conflicting provision in a document attached to or incorporated by reference into a schedule, unless the schedule expressly states otherwise.

16.17 This Agreement does not operate as a permit, license, approval or other statutory authority which you may be required to obtain from the Province or any of its agencies in order to provide the Services. Nothing in this Agreement is to be construed as interfering with, or fettering in any manner, the exercise by the Province or its agencies of any statutory, prerogative, executive or legislative power or duty.

16.18 If any provision of this Agreement or the application of it to any person or circumstance is invalid or unenforceable to any extent, the remainder of this Agreement and the application of such provision to any other person or circumstance will not be affected or impaired and will be valid and enforceable to the extent permitted by law.

16.19 Each party must perform the acts, execute and deliver the writings, and give the assurances as may be reasonably necessary to give full effect to this Agreement.

16.20 This Agreement is governed by, and is to be interpreted and construed in accordance with, the laws applicable in British Columbia.

ARTICLE 17 INTERPRETATION

17.01 In this Agreement:

(a) "we", "us", and "our" refer to the Province alone and never refer to the combination of the Contractor and the Province;

(b) the Contractor and the Province are referred to as "the parties" and each of them as a "party";

(c) "includes" and "including" are not intended to be limiting;

(d) unless the context otherwise requires, references to sections by number are to sections of this Agreement;

(e) "attached" means attached to this Agreement when used in relation to a schedule;

(f) unless otherwise specified, a reference to a statute by name means the statute of British Columbia by that name, as amended or replaced from time to time;

(g) the headings have been inserted for convenience of reference only and are not intended to describe, enlarge or restrict the scope or meaning of this Agreement or any provision of it;

(h) "person" includes an individual, partnership, corporation or legal entity of any nature; and

(i) unless the context otherwise requires, words expressed in the singular include the plural and *vice versa*.

ARTICLE 18 EXECUTION AND DELIVERY

18.01 This Agreement may be entered into by a separate copy of this Agreement being executed by, or on behalf of, each party and that executed copy being delivered to the other party by a method provided for in Section 16.01 or any other method agreed to by the parties.

The Parties have executed this Agreement as follows:

SIGNED AND DELIVERED on behalf of the Province by an authorized representative of the Province	**SIGNED AND DELIVERED** by or on behalf of the Contractor (or by an authorized signatory of the Contractor if a corporation)
(Authorized Ministry Expense Authority)	(Contractor or Authorized Signatory)
Shane Berg	**Denis Cormier**
(PRINTED NAME of Ministry Expense Authority)	(PRINTED NAME of Contractor)
Dated this 4 day of JUNE, 2019	Dated this 3rd day of June, 2019

BRITISH COLUMBIA

Natural Resource Ministries

Contract Modification Agreement No. 1

MINISTRY CONTRACT/FILE NO.: 1070-20/FH20FHQ067

PROJECT NAME: Glyphosate Policy Review

THIS MODIFICATION AGREEMENT dated for reference September 18, 2019.

BETWEEN

HER MAJESTY THE QUEEN IN RIGHT OF THE PROVINCE OF BRITISH COLUMBIA, represented by the MINISTER OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT

(the "Province", "we", "us", or "our" as applicable) at the following address:

ADM's Office of the Chief Forester
3rd floor, 727 Fisgard Street
Victoria, BC V8W 9C2

Telephone: 250-896-9911

Business E-mail Address: Shawn.Hedges@gov.bc.ca

Ministry Representative: Shawn Hedges

AND

FP Innovations

(the "Contractor", "you", or "your" as applicable) at the following address:

2665 East Mall
Vancouver, BC V6T 1W5

Telephone: 604-222-5618

Fax: N/A

E-mail Address: JimHunt@shaw.ca

Contractor Representative: Jim Hunt

Corporate Business Number: A0071162 Extraprovincial Company

WorkSafe BC No: 795598 AA(001) **and/or** POP No.

A. The Parties entered into an Agreement dated for reference May 27, 2019, (hereinafter called the "Agreement"),

B. The Parties agree to amend the Agreement as follows:

1. Reduce the maximum Expenses payable set out in Schedule B, paragraph 2.02 from $5,000 to $500.
2. Increase the maximum Fees payable set out in Schedule B, paragraph 1.02, from $70,000 to $74,500 (Nb. No change to total net total contract value).

C. The Parties agree to Change the Work as follows.

The Contractor agrees to perform forthwith the following Work as extra work or reduction of work, subject to the terms and conditions of the Agreement and to be paid for or credited in accordance with the said terms of the contract.

CONTRACT MODIFICATION AGREEMENT

CONTINUED

Unless otherwise indicated, lump sum or unit prices shown below constitute full payment for all labour, materials, equipment, overhead, profit, taxes (including taxes paid or payable by you to a supplier) and other things required to completely incorporate the change(s) into the contract work, but exclusive of Goods and Services Tax (GST) and any applicable Provincial Sales Tax (PST) that you are required to charge the Province as a taxable transaction.

CHANGE OF WORK		
ITEM NO.	**DESCRIPTION OF WORK ADDED / DELETED, INCLUDING QUANTITIES**	**PRICE**
1.	**$**4,500 To address increased work related to stakeholder consultation and data analysis	$4 500

As Per Quotation Dated	Y M D 2019/09/17	Total Price for Additions (PST and GST excluded)	$4 500	Total Credit for Deletions	$
Recommended and submitted by (Contract Manager/Inspector): Shawn Hedges					

D. In all other respects, the Agreement is confirmed.

E. Time is of the essence in this Modification Agreement.

The Parties duly execute this Modification Agreement as follows:

SIGNED AND DELIVERED on behalf of the Province by an authorized representative of the Province	**SIGNED AND DELIVERED** by or on behalf of the Contractor (or by an authorized signatory of the Contractor if a corporation)
(Signature of authorized Ministry Expense Authority)	(Signature of Contractor or Authorized Signatory)
Shane Berg	Denis Cormier
(PRINTED NAME of authorized representative)	(PRINTED NAME of Contractor or authorized signatory)
Dated this 8 day of October 2019	Dated this 1 day of October 2019

BRITISH COLUMBIA

Natural Resource Ministries

Contract Modification Agreement No. 2

MINISTRY CONTRACT/FILE NO.: 1070-20/FH20FHQ067

PROJECT NAME: Glyphosate Policy Review

THIS MODIFICATION AGREEMENT dated for reference October 24th, 2019..

BETWEEN

HER MAJESTY THE QUEEN IN RIGHT OF THE PROVINCE OF BRITISH COLUMBIA, represented by the MINISTER OF FORESTS, LANDS, NATURAL RESOURCE OPERATIONS AND RURAL DEVELOPMENT

(the "Province", "we", "us", or "our" as applicable) at the following address:

ADM's Office of the Chief Forester
3rd floor, 727 Fisgard Street
Victoria, BC V8W 9C2

Telephone: 250-896-9911

Business E-mail Address: Shawn.Hedges@gov.bc.ca

Ministry Representative: Shawn Hedges

AND

FP Innovations

(the "Contractor", "you", or "your" as applicable) at the following address:

2665 East Mall
Vancouver, BC V6T 1W5

Telephone: 604-222-5618

Fax: N/A

E-mail Address: JimHunt@shaw.ca

Contractor Representative: Jim Hunt

Corporate Business Number: A0071162 Extraprovincial Company

WorkSafe BC No: 795598 AA(001) **and/or** POP No.

A. The Parties entered into an Agreement dated for reference May 27, 2019, (hereinafter called the "Agreement"),

B. The Parties agree to amend the Agreement as follows:

SCHEDULE B – PAYMENT

To increase total payable to $82,500.00. This is an increase of $7,500.00

C. The Parties agree to Change the Work as follows.

The Contractor agrees to perform forthwith the following Work as extra work or reduction of work, subject to the terms and conditions of the Agreement and to be paid for or credited in accordance with the said terms of the contract.

CONTRACT MODIFICATION AGREEMENT

CONTINUED

Unless otherwise indicated, lump sum or unit prices shown below constitute full payment for all labour, materials, equipment, overhead, profit, taxes (including taxes paid or payable by you to a supplier) and other things required to completely incorporate the change(s) into the contract work, but exclusive of Goods and Services Tax (GST) and any applicable Provincial Sales Tax (PST) that you are required to charge the Province as a taxable transaction.

CHANGE OF WORK		
ITEM NO.	**DESCRIPTION OF WORK ADDED / DELETED, INCLUDING QUANTITIES**	**PRICE**
	1. ***Additional focus areas assigned by the Glyphosate Policy Review Steering Committee may be assigned provided any increases in project scope correspond with an increased budget to cover additional costs.***	

As Per Quotation Dated Y M D	Total Price for Additions (PST and GST excluded)	Total Credit for Deletions
2019/10/24	$7,500	$
Recommended and submitted by (Contract Manager/Inspector): Shawn Hedges		

D. In all other respects, the Agreement is confirmed.

E. Time is of the essence in this Modification Agreement.

The Parties duly execute this Modification Agreement as follows:

SIGNED AND DELIVERED on behalf of the Province by an authorized representative of the Province	**SIGNED AND DELIVERED** by or on behalf of the Contractor (or by an authorized signatory of the Contractor if a corporation)
(Signature of authorized Ministry Expense Authority)	(Signature of Contractor or Authorized Signatory)
Shane Berg	Denis Cormier
(PRINTED NAME of authorized representative)	(PRINTED NAME of Contractor or authorized signatory)
Dated this 10 day of DEC. 2019	Dated this 9 day of December 2019

Begon, Stacey FLNR:EX

From: Hedges, Shawn FLNR:EX
Sent: December 11, 2019 3:09 PM
To: Berg, Shane FLNR:EX; Psyllakis, Jennifer FLNR:EX; Bedford, Lorne FLNR:EX; MacDougall, Julie FLNR:EX; Hughes, Neil FLNR:EX; Gordon, Steve M FLNR:EX; Mullan, Jonathan M ENV:EX; Zacharias-Homer, Christa ENV:EX
Cc: sitkaforestry@shaw.ca
Subject: Final FPI and BN
Attachments: Glyphosate Final 20191211.pdf; 252256 ADM BNI - Summary of FPI Glyphosate Review Report (Dec 11_19).docx

Colleagues, attached is the final glyphosate report I received earlier today from FPI. Also attached is a finalised briefing note for our Chief Forester. I'll be moving both forward later today via eApprovals.

I'll likely put pen to paper soon and start writing a second, shorter BC for our minister and senior executive providing them with a summary of what the report says and proposed next steps. I'll run this past the group when I've got something stable that I'm happy with.

_____

Shawn Hedges, RPF
Director, Sustainability & Forestry
Office of the Chief Forester
Forests, Lands, Natural Resource Operations & Rural Development
Cellular (250) 896-9911

FPInnovations

info@fpinnovations.ca
www.fpinnovations.ca

REVIEW OF GLYPHOSATE USE IN BRITISH COLUMBIA FORESTRY

PROJECT NUMBER: 301013763

Jim Hunt, Lead Scientist

Pamela Matute, Researcher

November 2019

FPInnovations

October 2019

The present is a review of current glyphosate use in British Columbia forestry, peer-reviewed forest science on the impacts of glyphosate use on forests, and input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in British Columbia was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishing forest stands post-harvest.

Project number: 301013763

ACKNOWLEDGEMENTS

This project was contracted by the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development

REVIEWERS
Ken Byrne, Manager, Fibre Supply

AUTHOR CONTACT INFORMATION
Pamela Matute
Researcher, Fibre Supply
pamela.matute@fpinnovations.ca
(604) 222-5698

APPROVER CONTACT INFORMATION
Shawn Hedges
Director, Sustainability and Forestry

shawn.hedges@gov.bc.ca

Disclaimer to any person or entity as to the accuracy, correctness, or completeness of the information, data, or any analysis thereof contained in this report, or any other recommendation, representation, or warranty whatsoever concerning this report.

Follow us

Table of contents

Executive Summary 1
1 Introduction 3
2 Use of Glyphosate in British Columbia Forests 4
2.1 Regulatory Framework 4
2.1.1 Free Growing 4
2.1.2 Herbicides 5
2.2 Why is Glyphosate Used? 6
2.2.1 Site Preparation 7
2.2.2 Plantation Survival 7
2.2.3 Crop Tree Productivity 7
2.2.4 Invasive Species 7
2.3 How is Glyphosate Used? 8
2.3.1 Area Treated 8
2.3.2 Glyphosate Use at the Stand Level 11
2.4 Treatment Costs 13
3 Impact of glyphosate use on non-timber values 14
3.1 Biodiversity 14
3.1.1 Broadleaf Tree Species 14
3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide treatment 14
3.1.1.2 RESULTS analyses 15
3.1.2 Non-Target Plant Communities 16
3.1.3 Aquatic Organisms 17
3.1.4 Wildlife 18
3.1.4.1 Toxicity 18
3.1.4.1 Forage quality and quantity 18
3.2 Soil and Water Quality 19
3.2.1 Glyphosate/aminomethylphosphonic acid fate in soils 19
3.2.2 Soil microorganisms 20
3.2.3 Glyphosate/aminomethylphosphonic acid fate in water 20
3.3 Climate Change 21

3.4 Wildfire 21
3.5 First Nations 22
3.6 Public Use 23
4 Impacts on Timber Supply 24
4.1 Managing for Multiple Values 25
5 Recommendations 26
6 Conclusions 27
7 References 28
Appendix 1. International Assessments 40
Appendix 2. Stocking Standards and Survey Changes Related to Deciduous Management in British Columbia 43
Appendix 3. Integrated Pest Management Principles 44
Glossary 51

EXECUTIVE SUMMARY

FPInnovations was contracted by the Office of the Chief Forester to undertake a review of current glyphosate use in British Columbia (B.C.) forestry including peer-reviewed forest science on the impacts of glyphosate use on forests, and input from stakeholders. The use of glyphosate in relation to the multiple values that are pertinent to forest management in B.C. was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishing forest stands post-harvest. The report will inform future policy development and research needs, with the main objective to promote the establishment of healthy and diverse forests.

The herbicide glyphosate is one of many vegetation management tools available to forest managers. As a tool for vegetation control, it is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. It is very effective because it is easily translocated within the target plant, and usually kills it and reduces the brush hazard for multiple years after a single application, unlike other motor-manual vegetation control methods. Glyphosate application may target aggressive competition from broad-leaved trees, shrubs, and herbaceous vegetation.

In 2018, approximately 11,000 ha of Crown land in B.C. were treated with glyphosate for silvicultural purposes. The total area treated with glyphosate was 7% of the area harvested on B.C. Crown land in 2018, and less than 0.5% of the area with outstanding reforestation obligations. In 2018, most (73%) of the glyphosate application was conducted in the Omineca Natural Resource Region. Of all the biogeoclimatic zones, the Sub-Boreal Spruce zone received the most glyphosate application (76%). Glyphosate was applied primarily aerially (86%); the remainder (14%) was applied using ground-based methods.

Public concerns over the impacts of glyphosate use on the ecosystem are growing, particularly regarding ecosystem changes resulting from the control of broadleaf trees such as trembling aspen. A RESULTS (Reporting Silviculture Updates and Land Status Tracking System) analysis of deciduous stand components at free growing showed that in the Omineca Natural Resource Region, where most of the glyphosate application occurs, deciduous components accounted for 15–21% of the stand density on sites that were previously treated with glyphosate. Data also show that in the B.C. Interior, mixed deciduous stands have been increasing over time as a result of forest management activities.

A summary of the many studies on the impact of glyphosate on forest soils, water, non-target plant communities, and wildlife is presented. While impacts can vary with site characteristics, research has shown that the risk of glyphosate and its metabolites on the environment is minimal when the herbicide is applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes to these communities are related to changes in vegetation structure and are transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects of glyphosate on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. Recent research has found low but unexpected levels of glyphosate residue in plants 1 year following treatment, which may have implications for wildlife forage quality, plant physiology, and

traditional food and medicine plant harvesting. While residue levels were non-toxic to humans and wildlife, little is known about their persistence and their effect on forage quality and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

Glyphosate remains an important tool for establishing conifer or conifer–deciduous mixed stands and ensuring future timber supply. Glyphosate bans in other jurisdictions in Canada have resulted in significant struggles to meet silvicultural objectives on the land base, which highlights glyphosate's important role in maintaining conifer productivity. Forest management in B.C. seeks to balance all values ascribed to the forest, with the overarching objective of establishing and maintaining healthy and diverse forests. While more research on the identified knowledge gaps is recommended, glyphosate needs to be considered in the context of these values and objectives, and with perspective regarding the amount of area treated, the apparent transient effects on the site's ecology, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels.

1 INTRODUCTION

Public pressure to reduce the use of glyphosate has been increasing in British Columbia (B.C.) and other jurisdictions. In response, the Office of the Chief Forester for the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) contracted FPInnovations to undertake a review of current peer-reviewed forest science and best practices on glyphosate use in B.C. forestry. Input from stakeholders was also solicited. The forestry use of glyphosate in relation to the multiple values pertinent to forest management in B.C. was considered. The report will inform future policy development and research needs, with the main objective to promote the establishment of healthy and diverse forests.

Successful regeneration of forests after timber harvesting often requires control of competing vegetation, which may cause mortality or reduced growth of established seedlings. Several vegetation management alternatives exist for this purpose, including chemical (e.g., glyphosate, triclopyr) and non-chemical (e.g., manual cutting, girdling, sheep grazing) methods.

Glyphosate-based herbicides are the most widely used in the world, largely due to their effectiveness, their safety for non-target species and the environment, and the development of glyphosate-tolerant agricultural crops. Several factors support the use of this herbicide in forestry applications in B.C.:

- ability to translocate within treated plants and control resprouting of perennial weeds;
- generally favourable environmental profile, including binding in soils and rapid biodegradation in most soils, water, and sediments;
- specific mechanism of action, inhibiting an enzyme found in plants;
- low toxicity to animals; and
- minimal impact on forest ecosystems (Rolando et al., 2017).

This report focuses on glyphosate application for silviculture as a vegetation management tool in re-establishing forest stands post-harvest. The use of glyphosate for agriculture, transmission or transportation corridors, or other industrial uses is outside the scope of this report. The effects of glyphosate on human health and the environment have been extensively reviewed by regulatory agencies (Appendix 1), including by Health Canada's Pest Management Regulatory Agency as recently as 2017 and again in 2019. These findings are summarized in Appendix 1.

2 USE OF GLYPHOSATE IN BRITISH COLUMBIA FORESTS

2.1 Regulatory Framework

2.1.1 Free Growing

In B.C., timber harvesting in public forests is regulated such that any harvested area must be reforested to an acceptable standard of free growing. The *Forest Range and Practices Act* (sec 1) defines "free growing" as "a stand of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees". A free-growing stand is expected to contribute to landscape objectives and to a sustainable long-term fibre supply.

The Forest Planning and Practices Regulation (FPPR) (sec 44) addresses obligations to produce a free-growing stand that meets applicable stocking standards approved in a Forest Stewardship Plan (FSP) by specified dates. Stocking standards are regulatory tools that ensure that the re-establishment of a forest stand post-harvest is aligned to large-scale objectives for the land base as set out in FSPs. Stocking standards specify regeneration requirements such as suitable tree species for the site, stand density, spacing, free-growing height, and ratio of crop tree height to surrounding competing vegetation.

Sec 46.11 of the FPPR indicates that these silvicultural obligations must be fulfilled on each hectare within the net area to be reforested, unless otherwise specified in an FSP. Mappable areas that do not meet stocking standards should not exceed 2 ha or 5% of the Standards Unit area. Under the FPPR (sec 97.1), an obligation holder may be relieved of the obligation to meet stocking standards if they can prove that obligations have been met to the extent that is practicable.

Sec 26 (5) of the FPPR also provides a mechanism for developing stocking standards in an FSP that are not consistent with current timber supply assumptions. The review test for sec 26 (5) requires the delegated decision maker to be satisfied that the regeneration date and stocking standards are reasonable, having regard for future timber supply and the set values ascribed to forest land.

Free-growing surveys are the tool that forest managers use to measure whether a stand meets free-growing obligations. Survey methods, including quantification of shrub and broadleaf competition, are described in the Silviculture Surveys Procedures Manual.

Stocking standards and related guidance have evolved since the 1990s and continue to evolve to incorporate current understanding of resource issues (e.g., broadleaf species) and their impact on timber supply and other forest values. A summary of these developments is described in Appendix 2.

2.1.2 Herbicides

Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada to ensure that pesticides pose minimal risk to human health and the environment. Under authority of the *Pest Control Products Act*, Health Canada:

- registers pesticides after a stringent, science-based evaluation that ensures any risks are acceptable;
- re-evaluates the pesticides currently on the market on a 15-year cycle to ensure the products meet current scientific standards; and
- promotes sustainable pest management.

The latest PMRA re-evaluations of glyphosate safety were conducted in 2017 and then again shortly after in 2019 (PMRA 2017, 2019). Following the release of the re-approval decision in 2017, Health Canada received eight notices of objection that questioned the validity of the re-evaluation after revelations that several scientific publications may not have followed due scientific process in what came to be called the Monsanto Papers. After a scientific review of these claims and the publications in question, the PMRA issued a statement in January 2019 indicating that the objections did not cast doubt on the original 2017 decision, and that glyphosate remains approved for use in Canada (PMRA, 2019).

The *Integrated Pest Management Act* and Regulation (IPMR) sets out the requirements for the use and sale of pesticides in B.C. The B.C. Ministry of the Environment and Climate Change Strategy promotes Integrated Pest Management and environmental stewardship and ensures compliance with the *Integrated Pest Management Act* and Regulation. Large-scale pesticide programs (i.e., > 20 hectares per year of treatment area) that require Integrated Pest Management must have a confirmed Pest Management Plan (PMP). These plans document how the standards set in the IPMR will be implemented regarding environmental protection, notification, and herbicide handling and application, as well as alternatives to using herbicides. The content of PMPs is detailed in Appendix 3.

Integrated Pest Management is a process for managing pest populations. In a forestry context where competing vegetation is considered as a pest or weed, the following integrated vegetation management elements would apply:

- planning and managing ecosystems to prevent organisms from becoming weeds;
- identifying weed problems and potential weed problems;
- monitoring weed populations and weed complexes;
- using injury thresholds, levels at which pest numbers are high enough to cause unacceptable injury or damage, in making treatment decisions;
- selecting pest treatment methods based on:
    - consideration of practical alternatives to herbicide use,
    - protection of human health and the environment; and

- evaluating the effectiveness of weed management treatments.

Herbicides are rarely the only integrated vegetation management method used and are generally used in conjunction with other methods. Examples of best practices for implementing integrated vegetation management are included in Appendix 3.

2.2 Why is Glyphosate Used?

Managing competing vegetation is an essential part of reforestation efforts after forest harvesting. In B.C., vegetation management focuses on highly aggressive herbaceous complexes such as fireweed or bluejoint grass, and competitive deciduous trees such as red alder and trembling aspen. Targeted vegetation control is used in silviculture for two main reasons:

- to maintain plantation survival; and
- to meet free-growing obligations that ensure stand productivity and sustainable future timber supply.

Glyphosate is one of many chemical and non-chemical vegetation management tools available to forest managers (see Appendix 3 for other vegetation management alternatives). It may be applied aerially or with ground-based methods such as backpack sprayer, hack and squirt, cut stump, and vehicle-mounted sprayer. In recent years, backpack spraying has been the most common ground-based treatment used, while broadcast boom spraying with helicopters is the only aerial method used.

The primary benefit of using glyphosate is its effectiveness in controlling competing vegetation. Because it is easily translocated within the target plant, killing it outright, it can reduce the brush hazard for multiple years after a single application, as opposed to manual methods, which do not kill root systems and may result in re-sprouting of perennial weeds or stimulation of suckering by trembling aspen. Manual vegetation control treatments typically provide only short-term relief from competing vegetation, with control often lasting only for the balance of the growing season in which the treatment was applied (Miller 1985; Hart and Comeau 1992; Comeau et al., 1999, 2000). Several studies have found that a single manual treatment may be ineffective for sufficiently controlling cover to benefit seedling growth for more than a few years (Ehrentraut and Brantner 1990; Harper et al., 1997; 1998; Whitehead and Harper 1998; Comeau et al., 1999, 2000; Simard 2001; Heineman et al., 2005). The main manual methods used to control competing vegetation are brush saws, manual cutting, and power saws. Other methods such as girdling, sheep grazing, and stem bending using hockey sticks are used on a smaller scale due to their logistical difficulties and high cost.

The need for multiple treatments when relying on manual treatments, the higher cost associated with them, the increased safety risk to manual brushing workers, and the limited availability of brushing crews have helped make glyphosate a popular vegetation control alternative. No single vegetation control method suits all sites, however. Logistical, environmental, and safety concerns affect the choice of vegetation management. BC Timber Sales (BCTS) and licensees with reforestation obligations document when and how herbicides and other vegetation control methods are used in their Pest Management Plans (see Appendix 3).

Depending on the developmental stage of a plantation and its brush complex, glyphosate may be used to clear a planting site of pre-established brush, to reduce seedling competition in order to ensure plantation survival, or to meet free-growing requirements that ensure long-term productivity and timber supply, particularly where management is focused on specific timber species and outcomes.

2.2.1 Site Preparation

Glyphosate is sometimes used to prepare a site for planting where highly competitive vegetation complexes have become established prior to planting. Vegetation control before planting is preferred where it is expected that vegetation will impact plantable spots, target planting density, and plantation survival and growth. The average annual area of sites prepared with glyphosate between 2008 and 2018 was 152 hectares per year, which was less than 2% of the total area treated with herbicides, and mostly ground-based application was used.

2.2.2 Plantation Survival

Plantations on sites with aggressive competing vegetation complexes can fail within a year without effective vegetation management. In these cases, interventions are often needed to avoid excessive seedling mortality and plantation failure (Comeau et al., 1999; Biring et al., 2003; Comeau and Harper, 2009). This application of glyphosate is particularly important with herbaceous vegetation complexes for which mechanical cutting is not effective, such as bluejoint reed grass. Bluejoint reed grass is a serious competitor in northeastern B.C., where it often colonizes sites after harvest and forms thick colonies that can prevent establishment of shrub and tree species for upwards of 25 years if left uncontrolled (Dunbar et al., 2011). Glyphosate application on these sites can suppress the growth of competitive vegetation, thereby enabling tree seedlings to become established.

2.2.3 Crop Tree Productivity

To meet silvicultural objectives for the site, vegetation management may be required to release established crop trees that are overtopped by competing vegetation and at risk of becoming suppressed. A single application of glyphosate during the first few years after planting in high-brush sites has been shown to effectively improve conifer growth 9–20 years later in a wide range of plant communities in various ecosystems in B.C. (Harper et al., 1997; Whitehead and Harper 1998; Biring et al., 1999; Biring and Hays-Byl 2000; Simard 2001; Harper et al., 2005; Boateng et al., 2006; Macadam and Kabzems 2006). There is substantial variation in the magnitude of reported growth gains because they are dependent on the type, intensity, and duration of vegetation competition; in certain cases, the effects have been found to be significant but can also be short-term (Comeau et al., 1999; Heineman et al., 2005; Comeau and Harper, 2009).

2.2.4 Invasive Species

While the focus of this report is on the use of glyphosate in B.C. silviculture, the herbicide may also be used in forests to control the spread of noxious and invasive weeds across the province. The *Forest Range and Practices Act* (sec 47) indicates that a person who is conducting a forest or range practice must use measures to prevent the introduction or spread of prescribed species of

invasive plants, as listed in the Invasive Plants Regulation. The B.C. *Weed Control Act* requires all land occupiers to control the spread of noxious weeds on their land or premises.

British Columbia has four multi-agency Pest Management Plans (PMPs) for invasive plant management, which together cover the entire province and all invasive plant treatments in B.C. Ministry of Transportation and Infrastructure, FLNRORD, and BC Parks jurisdictions. In 2018, the total area treated with herbicides for control of invasive plant species in these jurisdictions was 1593 ha, 8% of which was treated with glyphosate.[1] However, glyphosate comprised as much as 80% of the total herbicide use in the South Coast PMP program due partly to the focus on Japanese knotweed control. For many noxious weeds, such as knotweeds and some invasive grasses, manual treatments are not effective. Ten-year results from a B.C. study that compared knotweed control methods indicated that manual treatments are ineffective and can actually cause the plants to spread further (C. Chadburn, personal communication, 2019).

Glyphosate products are also used in areas where a short half-life or immobility in the soil is required, where soils, gravels, or other materials may be moved in the future, or near private gardens or other sensitive features. Glyphosate is an important treatment for riparian zones where a significant portion of invasive plants/noxious weeds occur. It is the only herbicide that allows the regulated 10-m pesticide-free zone to be reduced to 1 m when using selective application methods.

2.3 How is Glyphosate Used?

2.3.1 Area Treated

Data from the RESULTS database show that approximately 11,000 ha of Crown land were treated with glyphosate for silvicultural purposes in 2018,[2] with 86% sprayed aerially and 14% sprayed using ground-based methods (Figure 1) (see Appendix 3 for descriptions of aerial, ground-based, and alternative treatment methods). The area sprayed has declined from an average of 13,802 ha from 2013 to 2018 and higher historical levels. The area sprayed in 2018 was 0.044% of the 25 million hectares available for harvesting in B.C. and 0.44% of the tenured area on Crown land that has an outstanding reforestation obligation.

The proportion of area harvested that has had any kind of vegetation control treatment decreased from 18 to 14% between 2008 and 2018. Over that time, herbicides, primarily glyphosate, were applied to half the treated area, while the rest of the area was treated using non-chemical methods (Figure 2), primarily clearing with brush saws (Figure 3). The use of brushing declined due partly to the increase in mountain pine beetle (MPB) salvage. As MPB salvage winds down, BCTS and Interior licensees are moving their harvesting operations to wetter sites with potentially greater brush hazards, which might result in an increase in the need for vegetation control.

---

[1] Compared to 11,000 ha treated with glyphosate in B.C. for silviculture.

[2] Includes aerial and ground-based brushing and site preparation treatments but excludes basal spray and stem bark spray silviculture methods, which do not apply to glyphosate-based herbicides. It may include some triclopyr application that was reported as backpack treatment method. Private land is not included.

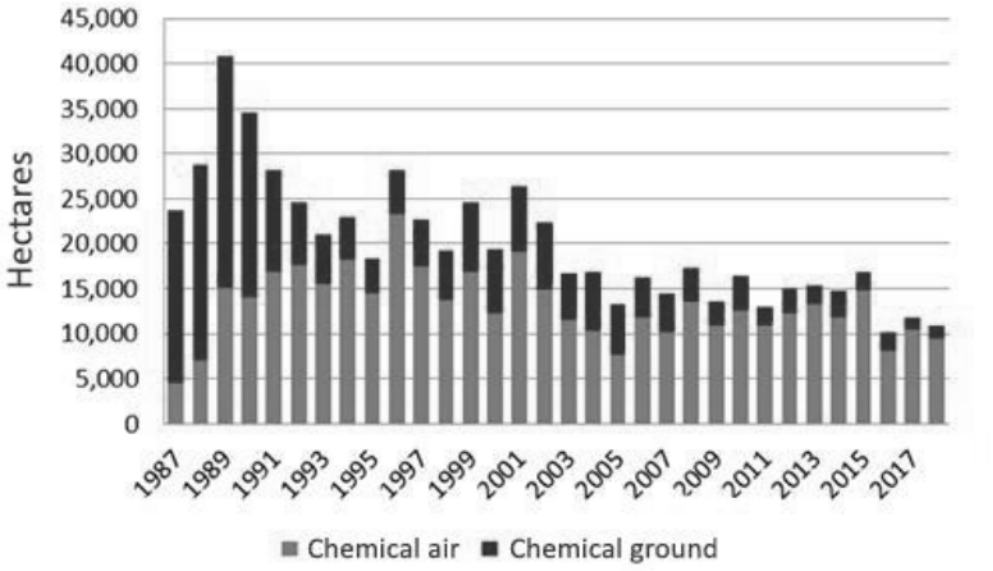


Figure 1. Area sprayed with glyphosate for silviculture in British Columbia.

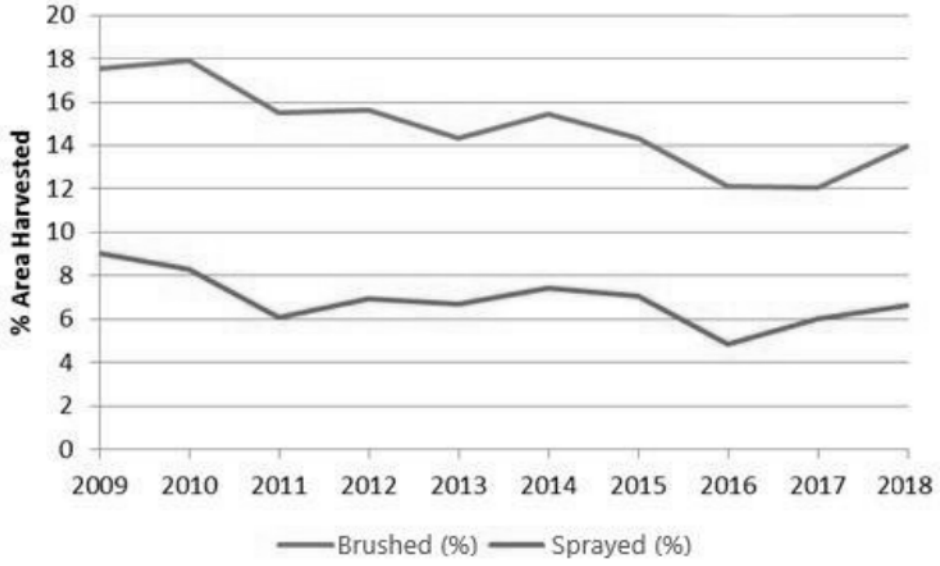


Figure 2. The percentage of harvested area that was brushed using alternative methods and sprayed with glyphosate.

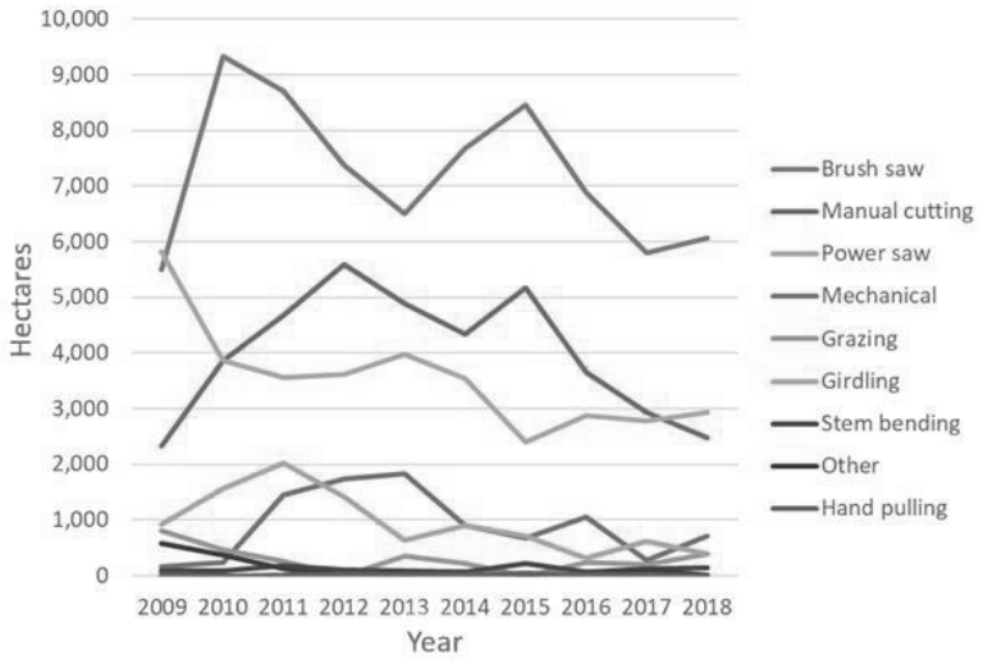


Figure 3. Area brushed using non-chemical methods.

Most of the glyphosate spraying was conducted in the Omineca Natural Resource Region (73% of all area treated), followed by the Northeast Region (11%) (Table 1). The Prince George Timber Supply Area comprised 68% of the total provincial area sprayed with glyphosate in 2018. Aerial applications made up 96% of the spray programs in those regions. Small aerial programs were also conducted in the Thompson-Okanagan and South Coast Regions. Small ground-based programs were conducted in all regions, with the largest occurring in the South Coast Region. The proportions of area harvested that were sprayed with glyphosate ranged from 11 to 15% in the Northeast, South Coast, and Omineca Regions, while less than 3% of the harvested area in the remaining regions was sprayed (Table 1).

Table 1. Area sprayed with glyphosate, by Natural Resource Region, in 2018

Natural Resource Region	Area harvested (ha)	Area treated with herbicide (ha)			% of harvest area
		Aerial	Ground-based	Total	
Omineca	52,795	7,673	301	7,974	15.1
Northeast	11,574	1,179	60	1,239	10.7
Thompson-Okanagan	25,635	565	18	583	2.3
South Coast	4,060	35	520	555	13.7
Kootenay-Boundary	14,333	0	234	234	1.6
West Coast	10,620	0	175	175	1.6
Skeena	16,346	0	169	169	1.0
Cariboo	28,418	0	39	39	0.1
B.C. total	**163,781**	**9,452**	**1,516**	**10,968**	**6.7**

The biogeoclimatic (BEC) zones (Meidinger and Pojar 1991) in which most of the glyphosate application was conducted were the Sub-Boreal Spruce (SBS) (76%) and Boreal White and Black Spruce (BWBS) (9%) zones (Table 2). Four subzones of the SBS accounted for 68% of the total provincial area that was sprayed (Figure 4). The drier SBS subzones (dry warm [dw] and moist cool [mk]) are generally dominated by aspen, while the wetter subzones (wet cool [wk] and very wet cool [vk]) are dominated by herbaceous vegetation.

Table 2. Area sprayed with herbicide, by biogeoclimatic zone, in 2018

BEC zone	Area treated with herbicide (ha)		
	Aerial	Ground-based	Total
Sub-Boreal Spruce (SBS)	7,865	416	8,281
Boreal White and Black Spruce (BWBS)	941	60	1,001
Coastal Western Hemlock (CWH)	27	662	689
Engelmann Spruce – Subalpine Fir (ESSF)	414	135	549
Interior Cedar – Hemlock (ICH)	195	192	387
Interior Douglas-fir (IDF)	0	52	52
Mountain Hemlock (MH)	8	0	8
B.C. total	**9,450**	**1,517**	**10,967**

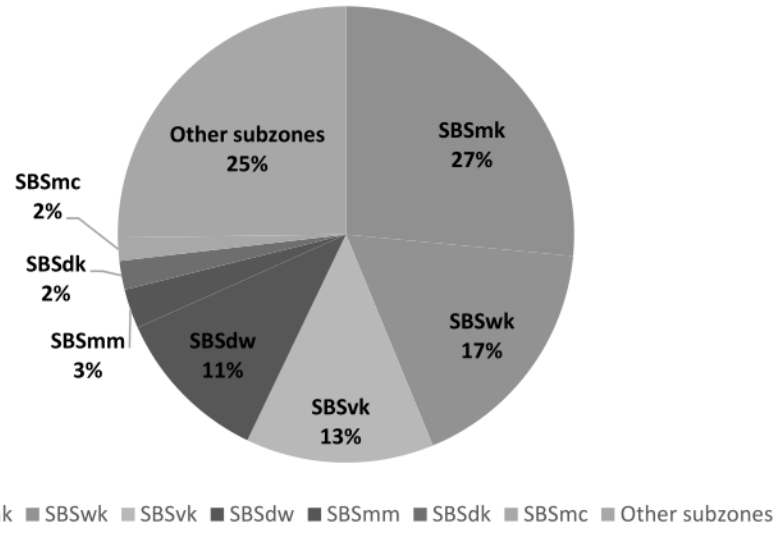


Figure 4. Herbicide use by biogeoclimatic subzone. (SBS: Sub-Boreal Spruce, mk: moist cook, wk: wet cool, vk: very wet cool, dw: dry warm, mm: moist mild, dk: dry cool)

2.3.2 Glyphosate Use at the Stand Level

Glyphosate is generally used in a targeted portion of the total reforestation area, as opposed to covering entire cutovers. In more than two-thirds of all cutovers treated with herbicide since

1998, the treatment area was less than 80% of the total net area to be reforested.[3] The distribution of net area to be reforested that was treated with herbicide is illustrated in Figure 5.

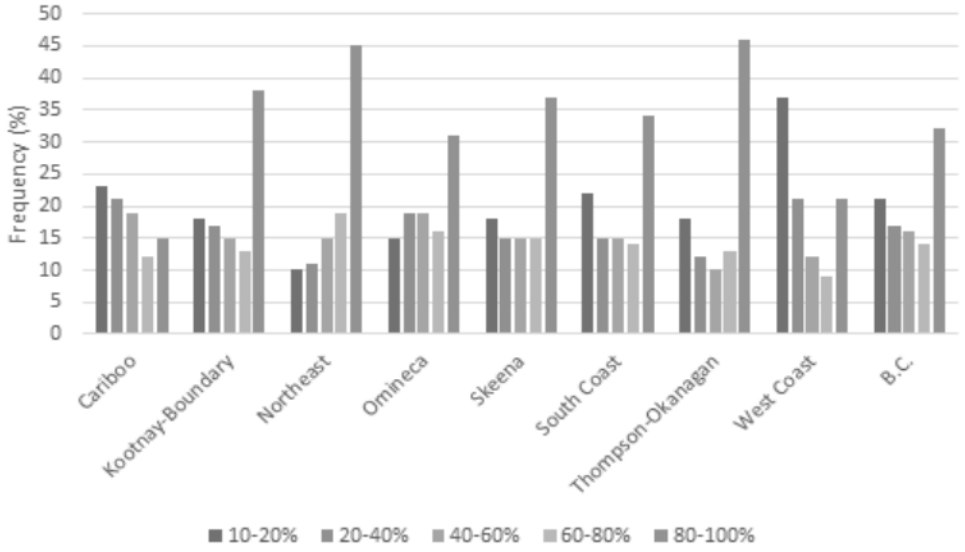


Figure 5. Distribution of the percentage of area treated with glyphosate within the net area to be reforested in a block, since 1998. Data is for one-time treatments only.

In contrast with agriculture and other common land uses where areas are sprayed repeatedly, in forestry, glyphosate is generally applied once or twice in a rotation. Since 1998, 47% of blocks that had ground-based herbicide treatments and 65% that had aerial treatments were treated once (Table 3). The percentage of blocks treated more than twice was 32% for ground-based and 11% for aerial treatments. The Coast regions had a higher proportion of retreatments than other regions. BC Timber Sales and licensees indicated that efforts are made to minimize areas sprayed to reduce costs and address public pressure.

Table 3. Number of herbicide treatments on a given area, since 1998

Natural Resource Region	Ground-based treatment			Aerial treatment		
	Number of treatments			Number of treatments		
	1	2	> 2	1	2	> 2
Cariboo	74%	20%	6%	83%	16%	1%
Kootenay-Boundary	44%	42%	14%	100%	0%	0%
Northeast	64%	25%	12%	53%	30%	17%
Omineca	89%	10%	1%	68%	24%	8%
Skeena	79%	11%	10%	70%	15%	15%
South Coast	41%	29%	30%	79%	21%	0%
Thompson-Okanagan	75%	17%	8%	45%	33%	22%
West Coast	24%	19%	58%	63%	25%	11%
B.C. total	**47%**	**21%**	**32%**	**65%**	**25%**	**11%**

[3] This analysis included blocks that were treated with herbicide only once.

Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species. Commonly targeted vegetation complexes in the SBS, where most of the glyphosate application occurs, are trembling aspen, mixed shrub, fireweed, and wet alder. The BWBS zone is dominated by aspen/poplar and reed grass complexes (Comeau et al., 1996).

Target species are indicated on brushing prescriptions that are developed from operational surveys. A licensee in the Prince George region indicated that 53% of the 2018 aerial spray area targeted aspen, while 47% targeted herbaceous/shrub competition. Aggregated data on which complexes are targeted the most by glyphosate application are currently lacking. More work is required to understand how glyphosate use is distributed among particular vegetation complexes or species to understand how and why glyphosate is used, and what the impact of not using it would be.

2.4 Treatment Costs

Treatment costs vary considerably depending on location, access, treatment intensity, availability of crews and equipment and logistics. BC Timber Sales and licensees reported that manual treatments (Can$700–$1200/ha) are more than twice the cost of glyphosate treatments (Can$300–$500/ha) and require at least two treatments. The cost of achieving free growing on a site that needs vegetation control ranges from Can$900 to Can$2100/ha more when using manual treatments. BC Timber Sales provided an example of treatment costs to attain free growing with and without glyphosate in the Prince George Region (Table 4). Assuming this example is representative and applying an average cost difference of $1400/ha to the 11,000-ha area that was sprayed in 2018, the cost of not using glyphosate for silviculture is estimated at Can$15.4 million per year.

Table 4. Cost of achieving free-growing, Prince George Region (Source: BC Timber Sales)

Activity	Vegetation management with glyphosate	Vegetation management with motor-manual treatments
Plant regular stock ($/ha)	$624	
Plant large stock ($/ha)		$900
Glyphosate application ($/ha)	$354	
Manual brush ($/ha) × 2		$1,460
Surveys	$70	$90
Cost to free-growing	**$1,048**	**$2,450**

Although costs are an important consideration, safety, access, crew availability, treatment windows, and various operational factors also affect the selection of treatment options discussed in Appendix 3.

3 IMPACT OF GLYPHOSATE USE ON NON-TIMBER VALUES

3.1 Biodiversity

The FPPR states that the objective set by the B.C. government for wildlife and biodiversity at the landscape level is, without unduly reducing the timber supply from British Columbia's forests and to the extent practicable, to design areas on which timber harvesting is to be carried out that resemble, both spatially and temporally, the patterns of natural disturbance that occur within the landscape.

3.1.1 Broadleaf Tree Species

Mixedwood forests provide various ecological, social, and non-timber values; have significant value in shaping forest ecology, stand structure, and function; and exert a strong influence on forest diversity and resilience (Harper and Roach 2014). One of the primary concerns the public has expressed regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broad-leaves are being eliminated from the landscape. These claims, however, are not supported by analyses of the amount of deciduous components remaining at free-growing in blocks that have been treated with glyphosate, or the increase in mixed deciduous stands over time as a result of forest management (BC MFLNRO 2008).

3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide treatment

On sites where aspen exists pre-harvest, it regenerates aggressively from suckering after a stand-replacing event such as fire or harvesting (Frey et al., 2003). This is particularly true in the boreal and sub-boreal mixedwoods that comprise large portions of central and northeastern B.C., where research has shown that in order to establish a conifer crop, vegetation management is often required to counter aspen suckering following harvesting[4] (Wood and von Althen, 1993; Cole et al., 2003; Pitt and Bell, 2005; Boateng et al., 2006).

On these sites, deciduous mixes often develop, even after conventional vegetation management treatments (including glyphosate) are used because a percentage of broad-leaves in a treated stratum may survive or produce suckers after treatment (Perala, 1985, Navratil et al., 1991; Bell and Newmaster, 2002; Pitt et al., 2004a, 2004b; Pitt and Bell, 2005; Kabzem and Harper, 2015). Medium- and long-term studies on the effect of a one-time glyphosate application on stand composition in boreal sites have recorded 15–21% deciduous stand components 5–30 years after treatment (Pitt et al., 2004a, 2004b; Pitt and Bell, 2005; Kabzem and Harper, 2015).

While those studies focused on deciduous composition within herbicide-treated areas, it is important to note that glyphosate is not generally applied to entire harvest units (see Section 2.3.2), and that the total elimination of competitive vegetation is not a silvicultural objective of conifer-release programs (Bell and Newmaster, 2002). In B.C., vegetation management

[4] Suckering from a single aspen parent tree can cover 500 m^2 at densities of up to 250,000 sph (Navratil et al. 1991)

treatments, including glyphosate application, are carried out only in the portions of a harvest unit where they are deemed necessary for conifer survival or to meet free-growing stocking standards in each standard unit as per sec 46.11 of the FPPR.

3.1.1.2 RESULTS analyses

A 2008 Forest and Range Evaluation Program review of tree species composition pre- and post-harvest in B.C. found that the amount of deciduous mixed stands at free growing increased from 2811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods (BC MFLNRO 2008). Similarly, in the Southern Interior Forest Region, deciduous mixed stands increased from 1202 ha before harvest to 37,268 ha at free growing, a 3000% increase.

An up-to-date RESULTS query of stand composition for all stands declared free growing following herbicide treatment (aerial and ground-based) was prepared by FLNRORD. The inventory labels from free-growing surveys were examined for openings that were sprayed > 5 years after harvest and surveyed 2–25 years after spraying. The data showed that province-wide, the average number of deciduous stems per hectare (sph) in a survey polygon after aerial and ground-based treatment was 504 and 449, respectively (Table 5). This corresponds to 16% and 15% broadleaf components (by stem density).

In the Omineca and Northeast Regions, where most herbicide treatments are conducted, the average number of deciduous stems per hectare at free growing after aerial herbicide treatments was 445 and 864, respectively, or 15% and 27% of the total stand species composition (Table 5). Similarly, in the SBS zone (the BEC zone where most herbicide application occurs), there was an average of 455 and 577 sph of deciduous at free growing for aerially and ground-based treated openings, respectively. The averages in Table 5 do not show the variation in sample sizes and stocking that can occur from year to year or among openings.

In general, for most regions, ground-based application resulted in a slightly higher number and percentage of deciduous stems at free growing compared with aerial application. Backpack-type application can be more selective compared to broadcast aerial treatments, and leave untreated stems between crop trees, which is less likely with aerial broadcast treatment.

Table 5. Deciduous stocking at free growing following aerial or ground-based herbicide treatments

Natural Resource Region	Deciduous components, post-aerial treatments		Deciduous components, post-ground-based treatments	
	Average deciduous density (sph)[a]	Deciduous component (%)	Average deciduous density (sph)	Deciduous component (%)
Omineca	445	14.7	699	21.2
Northeast	864	26.5	828	27.6
Cariboo	436	9.6	583	12.6
South Coast	94	4.8	120	7.2
Kootenay-Boundary	130	4.1	185	5.2
Skeena	237	8.9	230	7.7
Thompson-Okanagan	–	–	355	8.9
West Coast	–	–	449	14.6

B.C. Average	**504**	**16.4**	**449**	**14.6**

– Missing values indicate no survey data for the region.

[a] sph: stems per hectare

The results of the analysis suggest that deciduous stocking does recover after glyphosate spraying and may in fact be increasing over time with forest management activities. Deciduous components are important for many forest management objectives (e.g., wildlife habitat, wildfire, carbon), yet they also affect timber supply objectives. Research shows that increases in deciduous volume in a stand negatively affect conifer volume (Kabzems et al., 2007; Harper and Roach, 2014; Harper, 2015) (see Section 3.3).

3.1.2 Non-Target Plant Communities

3.1.2.1 Diversity of plant communities

A review of 12 studies found that species richness and diversity of non-target vascular plants was not negatively affected when measured 5–12 years after glyphosate application (Sullivan and Sullivan 2003). Studies report that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as 1–2 years after treatment (Freedman et al., 1993; Bell and Newmaster, 1998; Sullivan et al., 1998; Lautenschlager and Sullivan, 2002; Hawkins et al., 2013; Comeau and Fraser, 2018). In many cases, herbaceous vegetation abundance, diversity, and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank (Sullivan and Sullivan, 2003; Kabzems and Harper, 2015).

While broadcast aerial spraying of glyphosate is sometimes seen as a blunt vegetation management tool, studies have found that it does not target all vegetation equally. One study found that on sites with a vertical vegetation structure (comprised of aspen, shrubs, and forbs), most of the spray was deposited in the aspen canopy (68% of the nominal application rate), while shrubs and herbs captured approximately 25% and 12% of the nominal application rate, respectively, which may further help explain their quick recovery (Thompson et al., 1997).

Only two of the 12 studies Sullivan and Sullivan (2003) analyzed showed an overall reduction in species richness of shrubs after glyphosate application (Sullivan et al., 1998; Santillo et al., 1989). Santillo et al. (1989) found that species richness decreased by 50% and 30% for shrubs and herbs, respectively, 1 year after treatment and continued to be lower in the treatment units after 3 years. However, the control sites in this study were at a different successional stage than the glyphosate treatment units (Santillo et al., 1989). Sullivan et al. (1988) likewise observed a reduction in shrub species richness 5 years after treatment.

Other brushing alternatives such as manual brushing may have effects similar to glyphosate application on plant community composition. Lindgren and Sullivan (2001) compared manual cutting of stump sprouts and cut-stump application of glyphosate, and found no difference in species richness, diversity, structural diversity, or turnover of herbaceous, shrub, and tree communities. In a similar study, Bell and Newmaster (2002) showed that herbicides had a relatively greater initial effect on plant community composition compared to two mechanical vegetation control treatments, but that woody, herb, and grass layers recovered to pre-treatment levels within 5 years.

3.1.2.1 Persistence of glyphosate/aminomethylphosphonic acid in plant tissue

Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions (Gomes et al., 2014) due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least 1 year (Wood 2019). Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality; however, some translocation into shoots and fruit was observed in select plants (Wood 2019). While residue levels were non-toxic to humans and wildlife, little is known about the persistence timelines of residues, their effect on forage quality, and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

3.1.3 Aquatic Organisms

Amphibian populations are declining around the world (Houlahan et al., 2000), and chemical contaminants released into aquatic environments have been listed as the second most important threat to amphibians after habitat loss (Edge et al., 2011). Laboratory and mesocosm studies have shown direct effects of chronic exposures to glyphosate-based herbicides, particularly those containing the polyethoxylated tallow amine surfactant, on fish, amphibians, invertebrates, and other components of aquatic ecosystems (e.g., Folmar et al., 1979; Wan et al., 1989; Edglnton et al., 2004; Howe et al., 2004; Edge et al., 2014a, Lanctot et al., 2014, Navarro-Martin et al., 2014). However, studies have not been able to replicate these toxicity effects in the field under typical application rates and conditions.

Numerous whole-ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development (Edge et al., 2012, 2014b; Lanctot et al., 2013), expression of genes related to larval development (Lanctot et al., 2013), or juvenile amphibian survival (Edge et al., 2011, 2013). This is likely due to the short (but environmentally realistic and relevant) exposure duration (generally less than 96 hours) and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands (Edge et al., 2012, 2014b; Baker et al., 2016).

A watershed-level study in coastal B.C. found temporary stress effects and minor mortality (2.6%) in caged coho salmon smolt in an experimentally over-sprayed tributary and the main stream below the sprayed area immediately after glyphosate application. No acute mortality or changes in overwinter mortality, growth rate, or use of the tributary were observed for resident coho (Feng et al., 1990; Legris and Couture, 1991; Reynolds et al., 1993). Similarly, no effects on growth, behaviour, or histopathology of gills and livers of resident rainbow trout were found after a two-month exposure to herbicide in a separate tank experiment (Morgan and Kiceniuk, 1992).

Studies have found temporary effects on aquatic ecosystems due to changes in the vegetation after direct glyphosate application to water bodies. One study showed that glyphosate application caused a decrease in total macrophyte cover and species richness, an increase in species evenness, and a reduction in community similarity when compared to unexposed wetland sites (Baker et al., 2016). One year after herbicide applications, the wetland vegetation began to recover. Studies on aquatic macroinvertebrates have found similar results: one study found that 10% of the benthic macroinvertebrate taxa were eliminated after herbicide application but recovered in 1 year (Baker et al., 2014). Similarly, Linz (1999) reported no

negative effects and even increased arthropod abundance 1 year after direct overspray of a wetland. Rzymski et al. (2013) found no difference in taxa diversity but slight decreases in abundance of some taxa, which where hypothesized to be short term.

While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations require the maintenance of pesticide-free zones around water features, dry streams, and classified wetlands (IPMR, sec. 73 (1)), which further reduces the risk of negative effects on aquatic ecosystems. Various Canadian studies on surface water glyphosate residue have found no detectable glyphosate or AMPA concentrations (i.e., < 5000 ug a.i./L) post-treatment when using buffers of 100 m for aerial and 10–60m for ground applications (Eremko, 1986; Wan, 1986; Gluns, 1989; Adams et al., 2007). Canadian Water Quality Guidelines for the protection of aquatic wildlife stipulate maximum short-term and long-term glyphosate exposures of 27,000 ug a.i./L and 800 ug a.i./L, respectively[5] (CCME, 2012).

3.1.4 Wildlife

3.1.4.1 Toxicity

Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals, and birds have found risk quotients below the level of concern when typical field application rates were used (Giesy et al., 2000; Durkin et al., 2003; PMRA, 2015). Some uncertainty remains regarding the effects of long-term chronic exposure to low levels of glyphosate on wildlife due to glyphosate persistence in forage. While recorded residue levels were non-toxic to mammals, the effects of chronic sub-lethal exposure to mammals are not yet well-understood and require more research (Mesnage et al., 2015; Kissane and Sheppard, 2017; Wood, 2019).

Effects on terrestrial wildlife communities, like in aquatic ecosystems, are linked primarily to the changes in vegetation cover and forage quality. As such, species responses are highly variable and reflect individual habitat preferences. Studies on wildlife responses to habitat alteration due to glyphosate application have shown no effect, short-term negative effects, and positive effects on different wildlife species (Guynn et al., 2004). All in all, studies suggest that species richness and diversity of small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes are transient and related to changes in vegetation structure (Sullivan and Sullivan 2003).

3.1.4.1 Forage quality and quantity

Moose populations have been declining in several regions of B.C., and forage availability and quality has been flagged as a potential contributing cause (Kuzyk et al., 2018). Glyphosate treatment has been found to reduce wildlife forage availability in the short term (as compared to no vegetation control treatment), which results in reduced moose use of glyphosate-treated areas for the first few years after treatment (Hjeljord and Gronvold 1988; Connor and McMillan 1990; Lautesnschlager, 1993; Eschholz et al., 1996; Lautenschlager et al., 1999). The long-term impact of glyphosate use on habitat selection by moose is not well understood, however. Biring

[5] Values are based on median lethal dose (LC_{50}) data for 19 aquatic species.

et al. (1999) reported reduced forage abundance and use 12 years after glyphosate application in a BWBS site. However, Newton reported a 46% decrease in forage abundance the year following glyphosate application but a 660% increase at year 8 compared to the control (Newton et al., 1989), and some studies have shown that 7–11 years post-treatment, moose seem to favour treated areas over controls (Eschholz et al., 1996; Raymond et al., 1996). These impacts must also be considered in relation to the area that is treated annually and its distribution over the landscape (Lautenschlager and Sullivan 2002).

The effects of glyphosate's chelating properties on forage quality and nutrient availability are poorly understood. The properties allow glyphosate to bind macronutrients and micronutrients (in particular iron, manganese, zinc, copper, and nickel), which can impact uptake and availability in plants treated with glyphosate (Mertens et al., 2018). These micronutrients are particularly important to ungulates such as moose, whose sensitivities to mineral imbalances (in particular copper) have been implicated in moose population declines in Alaska, Sweden, and Minnesota (Flynn et al., 1977; Frank et al., 1994; O'Hara et al., 2001; Custer et al., 2004).

Studies on nutrient uptake by surviving plants in agricultural settings after glyphosate application have provided contradictory accounts (Gomes et al., 2014). In some cases, a reduced uptake of micronutrients by plants has been found (Eker et al., 2006; Cakmak et al., 2009; Tesfamariam et al., 2009), while in others (Duke et al., 2012, 2018), no effect on micronutrient content was found. More research on whether glyphosate application leads to reduced micronutrient content specifically in wildlife forage is required, and whether this is implicated in the moose population declines in B.C.

3.2 Soil and Water Quality

3.2.1 Glyphosate/aminomethylphosphonic acid fate in soils

After application, glyphosate is largely immobilized in the soil due to its strong sorption characteristics, which allow it to bind with soil particles and organic materials. Once glyphosate reaches the soil, the main pathway for its dissipation in soil is microbial degradation, as many species of soil microorganisms can use glyphosate as their soil carbon source (Durkin, 2003). One of the main compounds released during the microbial breakdown process, AMPA, is likewise adsorbed to soils and biodegraded, yet it is considered to be a mild phytotoxin (Reddy et al., 2004; Gomes et al., 2014) with relatively unknown long-term effects on soil organisms and plants.

Sorption and degradation processes are highly dependent on microbial activity and soil composition (Székács and Darvas, 2012). The rate of sorption and degradation of both glyphosate and AMPA vary greatly in agricultural applications, with half-lives ranging from a few days to several months, and even up to 1 year (Székács and Darvas, 2012). While it has been argued that the short growing season in northern climates may restrict degradation, North American studies in forest applications have found that the time for 50% dissipation (DT_{50}) in litter and soil is 8–19 days and 5–40 days, respectively (Newton et al., 1984, 1994; Feng and Thompson, 1990; Thompson et al., 2000; Hagner et al., 2019).

3.2.2 Soil microorganisms

Soil organisms play a crucial role in nutrient cycling and maintaining ecosystem productivity. Research on the effect of glyphosate on microorganisms in laboratory studies has been contradictory. Those studies have found exposure to glyphosate formulations may either reduce (Estok et al., 1989; Sanogo et al., 2000; Diaz et al., 2003; Tanney and Hutchinson, 2010; Druille et al., 2013; Zaller et al., 2014) or rarely stimulate (Laatikainen and Heinonen-Tanski 2002; Diaz et al., 2003) proliferation of certain fungal species. Laboratory studies on cultured microorganisms are likely to overestimate toxicity effects (Estok et al., 1989), however. Field studies on the effect of glyphosate application on forest soil organisms and microbial processes are limited, and their findings are often contradictory. Some detrimental effects on fungal communities and nutrient cycling have been documented (Vitousek et al. 1992; Munson et al. 1993). Similarly, annual applications of glyphosate in an Ontario plantation over a 5-year period have resulted in reduced microbial biomass and carbon, and a reduced soil organic carbon ratio, which indicates a reduced capacity of the ecosystem to maintain its nutrient reservoir (Ohtonen et al., 1992). In contrast, other field studies have found minimal or no effect on microbial processes or fungal community structures (Chakravarty and Chatarpaul, 1990; Stratton and Steward, 1992; Busse et al., 2001; Haney et al., 2002; Houston et al., 2002), while others have found a short-term increase in microbial activity caused by the breakdown of glyphosate and AMPA (Wardle and Parkinson 1990; Haney et al., 2002; Ratcliff et al., 2006; Mijangos et al., 2009). The extent of the variation in results suggests that more research on forest applications of glyphosate is needed to better understand direct effects on microbial communities. Research should examine effects on individual species and indirect impacts resulting from these changes in the ecosystem.

3.2.3 Glyphosate/aminomethylphosphonic acid fate in water

The mandated use of pesticide-free zones around water features, the strong sorption of glyphosate to upper soil layers, and the rapid uptake of glyphosate by plants minimize the risk of the herbicide entering aquatic ecosystems. The main ways that glyphosate could enter aquatic ecosystems are by drift onto non-target areas or by soil particle mobilization after a storm event in the hours following glyphosate application (Rolando et al. 2017). These risks may be minimized in field operations by using electronic guidance systems, low drift nozzles, and meteorological monitoring of wind speed, air temperature, and humidity (Thompson et al., 2012). Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are implemented (Gluns, 1989; Feng and Thompson 1990; Thompson et al., 2004; Adams et al., 2007).

Most North American field studies in streams and wetlands have shown that if glyphosate moves into water sources, its DT50 is less than 5 days, and there are no detectable residues after 15 days (Newton et al., 1984, 1994; Gluns, 1989; Goldsborough and Beck, 1989; Wan et al., 1989; Feng and Thompson, 1990; Thompson et al., 2004; Adams et al., 2007). One study in boreal ponds found a half-life of up to 11 days (Goldsborough and Brown, 1993).

The primary mechanisms involved in the rapid breakdown or reduction of glyphosate in the water column are adsorption into benthic or suspended sediments, microbial breakdown of glyphosate and its breakdown products, and downstream dilution. Glyphosate persists longer in oligotrophic water bodies or those that are cold and deep and have low microbial activity. Residues have been detected in benthic sediments of these systems up to 18 months after glyphosate application (Newton et al., 1984, 1994; Feng et al., 1990).

3.3 Climate Change

The Intergovernmental Panel on Climate Change notes that "in the long-term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit" (Nabuurs et al., 2007). Vegetation management (including, but not limited to, glyphosate application) can affect carbon sequestration due to its impact on vegetation structure and stand productivity. When used to control herbaceous or shrub vegetation, for example, it allows the establishment of a woody crop, which delivers immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools.

When competing species are aspen or other deciduous species, however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with the site and species. Mixedwood stands comprised of spruce and aspen are likely to have a higher yield than either pure spruce or pure aspen stands because of differences in shade tolerance, phenology, rooting patterns, and physical space occupied by different sized canopies (McCulloch and Kabzems 2009; Gough et al., 2019). Retaining between 1000 and 10,000 sph of aspen is expected to increase total stand production by approximately 20% relative to a pure spruce stand, but this will be at the expense of spruce volume (Kabzems et al., 2007). Harper and Roach (2014) similarly report that in a modelled mixedwood, the total stand volume was higher in a spruce–aspen mixedwood than in pure spruce or pure aspen stands.

Growth and yield models for the SBS show that total stand volumes in lodegepole pine–aspen stands are not different from those in pure aspen or pure pine stands (Harper, 2015). In all cases, the increase in deciduous volume is at the expense of conifer volume (Kabzems et al., 2007; Harper and Roach, 2014; Harper, 2015; Harper, 2017).

Forest soils are the largest carbon pool in boreal and temperate ecosystems, often storing greater amounts of carbon than living biomass and coarse woody debris (Heath et al., 2003). Laganiere et al. (2017) found that aspen trees stored less carbon in the forest floor and similar amounts in the mineral soil relative to conifers. However, their study also showed that soil organic carbon stock under aspen was more stable, which rendered it more protected against environmental changes and soil disturbances.

A source of uncertainty in determining the difference in carbon sequestration between mixedwoods and pure conifer stands is the shorter lifespan of deciduous trees compared to conifers, which ultimately affects the amount of time that a stand can act as a carbon sink (Harper and Roach, 2014).

3.4 Wildfire

Vegetation management (including, but not limited to, glyphosate application) has the potential to alter the number of deciduous trees left on a site after regeneration. Deciduous stands often act as natural fire breaks. In summer, deciduous stands moderate microclimates, inhibit wind movement, help maintain lower air temperature and higher humidity, and maintain soil and surface fuel moisture longer into the fire season when compared to conifer-dominated stands (Chesterman, 1997). The Canadian Forest Fire Behaviour Prediction System predicts that it takes more extreme moisture conditions for high-intensity fires to build in deciduous fuel types than in coniferous fuel types (Taylor et al., 1996).

The physical properties of aspen, in particular, resist intense fire behaviour, which makes it a popular choice for fuel treatments in the wildland–urban interface throughout North America (Shepperd et al., 2006; Gray 2018). Generally, fire does not get carried into the crowns of deciduous stands due to the absence of ladder fuels. Consequently, fires in deciduous stands are usually slower moving surface fires, which are easier to suppress than crown fires (Alexander and Lanoville, 2004). The Forest Fire Behaviour Prediction System indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous[6] or leaf-on mixedwood stands. Among deciduous trees, poplars show the most fire resistance (Table 6).

The effect of fire behaviour associated with deciduous vegetation that is treated with glyphosate is not well documented. It is expected that the fire hazard in dead stems following either manual or chemical treatment would be high because dead aspen burns very hot (R.W. Gray, personal communication, 2019).

Table 6. Fire resistance of broad-leaved species (BC MFLNRORD 2019)

Fire resistance/resilience	Broad-leaved species
High	Balsam poplar, black cottonwood
High–Moderate	Gary oak, bigleaf maple
Moderate	Trembling aspen, red alder, paper birch
Low	Arbutus

3.5 First Nations

Some First Nations in B.C. have expressed concern over the use of glyphosate in forests. Some of these concerns relate to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated. Chief Ron Ignace (Skeetchestn Indian Band) has indicated that he considers the spraying of herbicide “an act of cultural genocide, because you are killing our foods and medicines.”[7] The McLeod Lake Indian Band passed a Band Council resolution in July 2019 that reaffirms the Band’s zero tolerance for herbicide, pesticide, insecticide, and chemical fertilizer use within the traditional territory. The resolution indicates that glyphosate is deemed carcinogenic and has a direct impact on wildlife, ecosystems, and water sources. Where there is doubt concerning the science about herbicides, there can be an inclination toward the precautionary principle.

Two-way education, communication, collaboration, and joint problem-solving between stakeholders is key to reaching agreements about land use. Traditional plant users should, for example, take into consideration that the presence of glyphosate does not indicate toxicity (Wood, 2019) or that plant diversity, richness, and abundance is not generally affected in the years following application. Similarly, forest managers need to acknowledge and communicate uncertainty regarding minor effects of glyphosate use. There is mounting evidence, for example, that glyphosate/AMPA may persist in low levels in some perennial plants (Wood, 2019), and

[6] During spring, before leaf-out in deciduous stands, the grass has the potential to dry out rapidly in the absence of canopy cover, which creates a higher surface fire potential until green-up and leaf-on occurs.
[7] https://acuriouslookatpoliticsinbc.blogspot.com/2019/09/adam-olsen-skeetchestn-indian-band.html?fbclid=IwAR3kXSjKGMzGu6V5qs4Gxvu9l06PdbVbL5TtjdfWvallemumCz0TiAsRnaQ

that it may also disrupt the creation of some plant secondary compounds, some of which may be the compounds responsible for medicinal effects in traditional medicines (Gomes et al., 2014).

Relationship building between licensees and First Nations takes time and effort, but proactive and informed engagement can often solve problems. Discussion at the land use planning stage can help build mutual understanding, and ensuring that stakeholders understand silvicultural concepts of vegetation competition and the need for brushing to re-establish some stands after harvest will lead to more productive discussions.

Engagement with First Nations can also be conducted through the referral process within a PMP, which calls for meaningful consultation and accommodation. Licensees have indicated that within this framework, efforts can be, and often are, made to accommodate the specific concerns of First Nations by:

- designating no-spray areas;
- prioritizing manual treatments;
- prioritizing backpack instead of aerial application;
- prioritizing spot spray around individual stems;
- increasing buffers;
- leaving untreated patches;
- providing alternative plant gathering sites;
- providing additional notification and signage; and
- adjusting treatment schedules to avoid disrupting First Nations activities.

3.6 Public Use

Forest managers are faced with mounting public pressure over the safety of glyphosate use (Thomson and Pitt, 2011). Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts on human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping, or hiking. The Canada Pest Management Regulatory Agency's review on glyphosate (PMRA, 2017) addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health. This applies to people who may come in contact with glyphosate through food or water, by handling the product, or by entering treated sites.

Currently, there is no evidence that suggests that glyphosate application can cause game meat contamination because glyphosate has not been shown to accumulate in animal tissues (including in game species such as moose, deer, and hare) (Newton et al., 1984; Legris and Couture, 1991; Lautenschlager, 1992). Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, localized primarily in roots but sometimes found in shoot and fruit tissue (Wood, 2019). Where detected, glyphosate residue levels averaged 0.79 ppm (the highest level detected was 4 ppm) 1 year after

application. From a food consumption perspective, 0.1 ppm is the maximum residue level allowed for non-designated food in Canada, although this value ranges from 0.08 to 40.00 for specific foods. While the persistence timeline in forest plants is not well understood, persistence is expected to be more transient than in agricultural settings because in forestry, glyphosate is typically used only once or twice over an entire rotation.

Better communication between forest managers and recreational users about the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, can help address key public concerns and build trust. On-site signage after glyphosate treatment, which is currently required in B.C. under IPMR sec 63.1 and outlines safety precautions, could be used to address some of the current knowledge gaps (Wood, 2019).

4 IMPACTS ON TIMBER SUPPLY

Vegetation control, including but not limited to glyphosate application, is necessary in some cases to supress competing vegetation and allow crop trees to become established and grow unimpeded. The unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests. Vegetation management is one key tool for meeting these objectives.

Glyphosate is used in this context because of its cost-effectiveness compared to manual vegetation control methods. Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in not satisfactorily restocked area, particularly problematic areas, with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

In Canada, decisions to not use chemical herbicides have been made in Quebec and Nova Scotia. In Quebec, a provincial ban of glyphosate use on Crown land took effect in 2001 after severe public pressure and a series of public consultations. Forest regeneration focuses on early planting of tall stock and intensive manual brushing. Since then, plantation establishment and tending costs have frequently exceeded $5000/ha due to planting large stock and to the need to apply as many as three manual brushing treatments (Labbé et al., 2014). Dampier et al. (2006) reported that cost per cubic metre of wood tripled when conifer release was performed by motor-manual methods rather than aerial application of herbicide.

In addition to the increases in reforestation costs, there were challenges in managing plantations where the objective was to maximize wood production (Thiffault and Roy, 2011). Manual brushing alone was not effective in controlling competing vegetation and did not promote optimal crop tree growth due to rapid resprouting or suckering of competitors and competition from herbaceous species. Since the glyphosate ban, the Quebec Chief Forester's Office has reported challenges in reaching proper stocking throughout the province. In some areas, more than half the plantations have failed to meet required stocking due to severe competition (Bureau du forestier en chef, 2015).

An audit of plantations in Nova Scotia after a decision was made to not use herbicides yielded similar findings. Following a survey of untreated plantations, 87% of conifer plantations were

considered failures (with less than 60% stocking), and only 3% met free-growing standards 6–8 years post-harvest (Nicholson, 2007).

In B.C., meeting free-growing stocking standards ensures that sustainable timber supply is achieved. In cases where aggressive competing vegetation cannot be overcome to the extent that is practicable to meet free-growing requirements, licensees may request relief from reforestation obligations under FPPR sec 97.1. Increasing the challenge to meet reforestation obligations on a broad scale may increase the risk of reduced plantation performance with significant timber supply impacts, such as in Quebec.

4.1 Managing for Multiple Values

Forest management decisions related to achieving landscape objectives are reflected in stocking standards. Where stocking standards require the re-establishment of coniferous forests after harvest, with the objective of maintaining healthy forests and long-term fibre supply, studies show that competing vegetation control is necessary in some cases and that glyphosate is a highly effective vegetation control tool that has minimal and transient impacts on the ecosystem.

Where non-timber objectives such as increasing broadleaf stand components for wildfire risk reduction or wildlife are identified as priorities, current free-growing stocking standards may be overly restrictive (Harper and Roach, 2014). License holders have indicated that more flexibility and better guidance and support for alternative stocking standards could facilitate reduced brushing (including but not limited to glyphosate use) and accommodate other non-timber values. An example of one such mechanism is the Fort St. John pilot project, which allows for 2 ha, or 20%, of not satisfactorily restocked area over the landscape. The concept allows for areas of poor performance to be compensated by areas of superior performance, which in turn allows greater flexibility and efficiency of resources in areas where higher yields can be achieved, and avoids expensive, poor-value treatments, while accommodating non-timber values.

Landscape-level plans that link objectives to operational plans with a rationale for stocking standards could provide priorities for competing objectives on the land base.[8] For example, stocking standards in areas where managing for wildfire breaks or wildlife habitat are identified as priorities need to reflect a higher acceptance of broadleaf species over conifers, with the understanding that timber supply may be negatively affected. There are ongoing efforts to further develop standards that facilitate deciduous management in the context of overall forest management objectives. One example is the inclusion of fire stocking standards in the wildland–urban interface, including the establishment and management of deciduous species to reduce fire behaviour in areas near communities and infrastructure. In another example, a Hardwood Management Strategy was developed in 2008 to facilitate management of red alder, bigleaf maple, and birch in the Coast Region. Wildlife stocking standards are also being developed, and regional guidance is available.

[8] Challenges in addressing multiple forest management objectives such as timber supply, biodiversity, resilience, etc. at the operational level are identified in the Forest Practices Board's (2019) Special Report, *Tactical Forest Planning: The Missing Link Between Strategic and Operational Planning in BC.*

Alternative stocking standards for a Forest Stewardship Plan must be supported with science and justified with timber supply considerations and other tests as per FPPR 26(5). In some parts of the province, the focus on coniferous species remains a hurdle to applying alternative standards because the science for deciduous management is not well understood at the operational level. Licensees have indicated that further supporting research and guidance, such as that found in Newsome and Heineman's (2016) mixedwood stocking standards for the Cariboo Region, would assist them in developing stocking standards that can better incorporate other non-conifer values.

5 RECOMMENDATIONS

s.13

6 CONCLUSIONS

Glyphosate is one of many vegetation management tools available to forest managers. It is used to help maintain plantation survival and to meet free-growing obligations that ensure stand productivity and sustainable timber supply. Forest managers are faced with mounting public pressure over the perceived environmental impacts of forestry applications of glyphosate—in particular, concerns over the removal of broadleaf tree species from the landscape and the consequent impacts on risk of wildfire, wildlife habitat, resiliency, climate change, etc. A review of current inventory data, however, shows that stands that have been treated with glyphosate retain 15–21% deciduous components at free growing, and that the area comprised of deciduous–mixed stands has been increasing over time as a result of forest management activities in general.

Field studies have also shown that the effects of glyphosate and its metabolites on the environment are minimal when the herbicide is applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes to communities tend be transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects of glyphosate on soil microorganisms, its chelating effects on soil and plant nutrients, and its persistence in plants that survive treatment. More research is still needed to understand some of the impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.

While more research on the identified knowledge gaps is recommended, the use of glyphosate needs to be viewed from a landscape perspective, considering the amount of area treated, the short time scale of stand-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape levels. Put into perspective, vegetation management is just one component of the many silvicultural decisions that affect forest management in B.C. Many of the challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by building better linkages between site- and landscape-level planning that allows other non-timber values to be prioritized where needed.

7 REFERENCES

Adams, G. W., Smith, T., & Miller, J. D. (2007). The absence of glyphosate residues in wet soil and the adjacent watercourse after a forestry application in New Brunswick. *Northern Journal of Applied Forestry, 24*(3), 230–232.

Alexander, M. E., & Lanoville, R. A. (2004). The International Crown Fire Modelling Experiment fuel treatment trials [Abstract]. In R .T. Engstrom, K.E.M. Galley, & W.J. de Groot (Eds.). *Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems* (222). Tallahassee, FL : Tall Timbers Research Station.

Baker, L. F., Mudge, J. F., Houlahan, J. E., Thompson, D. G., & Kidd, K. A. (2014). The direct and indirect effects of a glyphosate-based herbicide and nutrients on Chironomidae (Diptera) emerging from small wetlands. *Environmental Toxicology and Chemistry, 33*, 2076–2085.

Baker, L. F., Mudge, J. F, Thompson, D. G, Houlahan, J. E, & Kidd, K. E. (2016). The combined influence of two agricultural contaminants on natural communities of phytoplankton and zooplankton. *Ecotoxicology , 25*, 1021–1032.

Bell, F. W., & Newmaster, S. G. (2002). The effects of silvicultural disturbances on the diversity of seed-producing plants in the boreal mixedwood forest. *Canadian Journal of Forest Research, 32*(7), 1180–1191. Retrieved from https://digitalcommons.usu.edu/aspen_bib/389

Bell, F.W., and Newmaster, S.G. (1998). Falling snow ecosystem project: floral richness, abundance and diversity. In Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability—Popular Summaries, 1998, Sault Ste.-Marie, Ont. Compiled by R.G. Wagner and D.G. Thompson. Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, Ont. For. Res. Inf. Pap. 141. pp. 45–47

Biring, B. S., Comeau, P. G., & Fielder, P. (2003). Long-term effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia. *Annals of Forest Science, 60*(7), 681-690.14.
Biring, B. S., & Hays-Byl, W. J. (2000). *Ten-year conifer and vegetation responses to glyphosate treatment in the SBSdw3*. (Extension Note 46). Victoria, BC: B.C. Ministry of Forests.

Biring, B. S., Hays-Byl, W. J., & Hoyles, S. E. (1999). *Twelve-year conifer and vegetation responses to discing and glyphosate treatments on a BWBSmw backlog site* (Working Paper 43). Victoria, BC: B.C. Ministry of Forests.

Boateng, J. O., Heineman, J. L., McClarnon, J., & Bedford, L. (2006).Twenty year responses of white spruce to mechanical site preparation and early chemical release in the boreal region of northeastern British Columbia. *Canadian Journal of Forest Research, 36*, 2386–2399.

British Columbia Ministry of Forests, Lands and Natural Resource Operations (BC MFLNRO). (2008). *Tree species composition and diversity in British Columbia* (FREP Report #14). Victoria, BC.

British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development (BC MFLNRORD). (2018). *Silviculture surveys procedures manual: regen delay, stocking and free growing surveys plus alternative survey methodologies*. Victoria, BC. Retrieved from https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

Bureau du forestier en chef. (2015). Succes des plantations. Avis du Forestier en chef. FEC-AVIS-04-2015, Roberval, Québec.

Busse, M. D., Ratcliff, A. W., Stestak, C.J., & Powers, R. F. (2001). Glyphosate toxicity and the effects of long-term vegetation control on soil microbial communities. *Soil Biology & Biochemistry, 33*, 1777–1789.

Canadian Council of Ministers of the Environment (CCME). (2012). Canadian water quality guidelines for the protection of aquatic life: glyphosate. In *Canadian environmental quality guidelines*. Winnipeg , MB.

Cakmak, I., Yazici, A., Tutus, Y., & Ozturk, L. (2009). Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium, and iron in non-glyphosate resistant soybean. *European Journal of Agronomy, 31*(3), 114–119.

Chakravarty, P. , & Chatarpaul, L. (1990). Non-target effect of herbicides: II. The influence of glyphosate on ectomycorrhizal symbiosis of red pine (*Pinus resinosa*) under greenhouse and field conditions. *Pesticide* S*cience*, *28*(3), 243–247.

Chesterman, D. A. 1997. *Microclimate of aspen forests*. (Unpublished master's thesis). University of Alberta, Edmonton, AB.

Cole, E., Youngblood, A., & Newton, M. (2003). Effects of competing vegetation on juvenile white spruce (*Picea glauca*(Moench)Voss) growth in Alaska. *Annals of Forest Science, 60*, 1–11.

Comeau, P.G., Braumandl, T.F. and Xie, C.Y. (1993). Effects of overtopping vegetation on light availability and growth of Engelmann spruce (Picea engelmannii) seedlings. *Canadian Journal of Forest Research*, 23(10), pp.2044-2048.

Comeau, P. G., Biring, B. S., & Harper, G. J. (1999). *Conifer response to brushing treatments: a summary of British Columbia data* (Extension Note 41). Victoria, BC: B.C. Ministry of Forests.

Comeau, P. G., Biring, B. S., & Harper, G. J. (2000). Effectiveness of repeated manual cutting and glyphosate for release of Engelmann spruce from mixed-shrub herb vegetation. *Western Journal of Applied Forestry, 15*(3), 154–162. http://dx.doi.org/10.1093/wjaf/15.3.154

Comeau, P., & Fraser, E. (2018). Plant community diversity and tree growth following single and repeated glyphosate herbicide applications to a white spruce plantation. *Forests, 9*(3), 107.

Comeau, P. G., & Harper, G. J. (2009). Effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia Year 15 results. *Forestry Chronicle, 85*(4), 583–592.

Comeau, P. G., Harper, G., Blache, M. E., Boateng, J. O., & Gilkeson, L. (1996). Integrated forest vegetation management: options and applications. In P. G. Comeau, G. J. Harper, M. E. Blache, J. O. Boateng, & L. A. Gilkeson (Eds.). *Proceedings of the Fifth B.C. Forest Vegetation Management Workshop* (FRDA Report 51). Victoria, BC: B.C Ministry of Forests & B.C, Ministry of Environment, Lands and Parks.

Connor, J. F., & McMillan, L. M. (1990). *Winter utilization by moose of glyphosate-treated cutovers*. Toronto, ON: Ontario Ministry of Natural Resources.

Custer, T. W., Cox, E., & Gray, B. (2004). Trace elements in moose (*Alces alces*) found dead in northwestern Minnesota, USA. *Science of the Total Environment, 330*(1), 81–87.

Dampier, E. E., Bell, F. W., St-Amour, M., Pitt, D. G., & Luckai, N. J. (2006). Cutting versus herbicides: tenth-year volume and release cost-effectiveness of sub-boreal conifer plantations. *Forestry Chronicle, 82*(4), 521–528. Retrieved from https://pubs.cif-ifc.org/doi/10.5558/tfc82521-4

Diaz, G., Carrillo, C., & Honrubia, M. (2003). Differential responses of ectomycorrhizal fungi to pesticides in pure culture. *Cryptogamie Mycologie, 24*, 199–211.

Druille, M., Cabello, M. N., Omacini, M., & Golluscio, R. A. (2013). Glyphosate reduces spore viability and root colonization of arbuscular mycorrhizal fungi. *Applied Soil Ecology, 64*, 99–103.

Duke, S. O., Lydon, J., Koskinen, W. C., Moorman, T. B., Chaney, R. L., & Hammerschmidt, R. (2012). Glyphosate effects on plant mineral nutrition, crop rhizosphere microbiota, and plant disease in glyphosate-resistant crops. *Journal of Agricultural and Food Chemistry, 60*(42), 10375–10397.

Duke, S. O., Rimando, A. M., Reddy, K. N., Cizdziel, J. V., Bellaloui, N., Shaw, D. R., Williams, M. M., & Maul, J. E. (2018). Lack of transgene and glyphosate effects on yield, and mineral and amino acid content of glyphosate-resistant soybean. *Pest Management Science, 74*(5), 1166–1173.

Dunbar, J., McCulloch, L., & Kabzems, R. (2011). Bluejoint stand establishment decision aid. *Journal of Ecosystems and Management, 11*(3).

Durkin, P. R. (2003). *Glyphosate - human health and ecological risk assessment report*. Fayetteville, NY: Syracuse Environmental Research Associates Inc.

Edge, C. B., Gahl, M. K., Pauli, B. D, Thompson, D. G., & Houlahan, J.E. (2011). Exposure of juvenile green frogs (*Lithobates clamitans*) in littoral enclosures to a glyphosate-based herbicide. *Ecotoxicology and Environmental Safety, 74*, 1363–1369.

Edge, C., Gahl, M., Thompson, D., Hao, C., & Houlahan, J. (2014a). Variation in amphibian response to two formulations of glyphosate-based herbicides. *Environmental Toxicology and Chemistry, 33,* 2628–2632.

Edge, C. B., Gahl, M. K., Thompson, D. G., & Houlahan, J. E. (2013). Laboratory and field exposure of two species of juvenile amphibians to a glyphosate-based herbicide and *Batrachochytrium dendrobatidis*. *Science of the Total Environment, 444*, 145–152.

Edge, C. B., Thompson, D. G., Hao, C., & Houlahan, J. E. (2012). A silviculture application of the glyphosate-based herbicide VisionMAX to wetlands has limited direct effects on amphibian larvae. *Environmental Toxicology and Chemistry, 31*, 2375–2383.

Edge, C., Thompson, D., Hao, C., & Houlahan, J. (2014b). The response of amphibian larvae to exposure to a glyphosate-based herbicide (Roundup WeatherMax) and nutrient enrichment in an ecosystem experiment. *Ecotoxicology and Environmental Safety, 109*, 124–132.

Edginton, A. N., Sheridan, P. M., Stephenson, G. R., Thompson, D. G., & Boermans, H. J. (2004). Comparative effects of pH and Vision® herbicide on two life stages of four anuran amphibian species. *Environmental Toxicology and Chemistry: An International Journal*, *23*(4), 815–822.

Ehrentraut, G., & Brantner, K. (1990). Vegetation management by manual and mechanical means in Alberta boreal forests. *Forestry Chronicle, 66*, 366–368.

Eker, S., Ozturk, L., Yazici, A., Erenoglu, B., Romheld, V., & Cakmak, I. (2006). Foliar-applied glyphosate substantially reduced uptake and transport of iron and manganese in sunflower (*Helianthus annuus* L.) plants. *Journal of Agricultural and Food Chemistry, 54*(26), 10019–10025.

Eremko, R.D. (1986). *The effects of the aerial application of Roundup on water quality in the Nicoamen River watershed*. Unpublished report. B.C. Ministry of Forests and Lands, Lillooet District.

Eschholz, W. E., Servello, F. A., Griffith, B., Raymond, K. S., & Krohn, W. B. (1996). Winter use of glyphosate-treated clearcuts by moose in Maine. *Journal of Wildlife Management, 60*, 764–769.

Estok, D., Freedman, B., & Boyle, D. (1989). Effects of the herbicides 2,4-D, glyphosate, hexazinone, and triclopyr on the growth of three species of ectomycorrhizal fungi. *Bulletin of Environmental Contamination and Toxicolology, 42*(6), 835–839. doi:10.1007/BF01701623

Feng, J. C., & Thompson, D. G. (1990). Fate of glyphosate in a Canadian forest watershed. 2. Persistence in foliage and soils. *Journal of Agricultural and Food Chemistry, 38*(4), 1118–1125.

Feng, J. C., Thompson, D. G., & Reynolds, P.E. (1990). Fate of glyphosate in a Canadian forest watershed. 1. Aquatic residues and off-target deposit assessment. *Journal of Agricultural and Food Chemistry, 38*(4), 1110–1118.

Flynn, A., Franzmann, A. W., Arneson, P. D., & Oldemeyer, J. L. (1977). Indications of copper deficiency in a subpopulation of Alaskan moose. *Journal of Nutrition, 107*(7), 1182–1189.

Folmar, L. C., Sanders, H. O., & Julin, A. M. (1979). Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. *Archives of Environmental Contamination and Toxicology, 8*(3), 269–278. https://doi.org/10.1007/BF01056243

Frank, A., Galgan, V., & Petersson, L. R. (1994). Secondary copper deficiency, chromium deficiency and trace element imbalance in the moose (*Alces alces* L.): effect of anthropogenic activity. *Ambio, 23*(4–5), 315–317.

Freedman, B., Morash, R., & MacKinnon, D. (1993). Short-term changes in vegetation after the silvicultural spraying of glyphosate herbicide onto regenerating clearcuts in Nova Scotia, Canada. *Canadian Journal of Forest Research, 23*(10), 2300–2311.

Frey, B. R., Lieffers, V. J., Landhäusser, S. M., Comeau, P. G., & Greenway, K. J. (2003). An analysis of sucker regeneration of trembling aspen. *Canadian Journal of Forest Research, 33*(7), 1169–1179.

Giesy, J. P., Dobson, S., & Solomon, K. R. (2000). Ecotoxicological risk assessment for Roundup® herbicide. In G.W. Ware (Ed.). *Reviews of environmental contamination and toxicology*. (Vol 167, 35–120). New York, NY: Springer.

Gluns, D. R. (1989). *Herbicide residue in surface water following an application of Roundup® in the Revelstoke Forest District* (RR 88001-NE). B.C. Ministry of Forests and Lands.

Goldsborough, L. G., & Beck, A. E. (1989). Rapid dissipation of glyphosate in small forest ponds. *Archives of Environmental Contamination and Toxicology*, *18*(4), 537–544.

Goldsborough, L. G., & Brown, D. J. (1993). Dissipation of glyphosate and aminomethylphosphonic acid in water and sediments of boreal forest ponds. *Environmental Toxicology and Chemistry 12*(7), 1139–1147.

Gomes, M. P., Smedbol, E., Chalifour, A., Hénault-Ethier, L., Labrecque, M., Lepage, L., Lucotte, M., & Juneau, P. (2014). Alteration of plant physiology by glyphosate and its by-product aminomethylphosphonic acid: an overview. *Journal of Experimental Botany*, *65*(17), 4691–4703.

Gough, C. M, Atkins, J. W., Fahey, R. T., & Hardaman, B.S. (2019). High rates of primary production in structurally complex forests. *Ecology, 100*(10). https://doi.org/10.1002/ecy.2864

Gray, R. W. (2018). *Trembling aspen stands as firebreaks: what options are available for stimulating aspen stand expansion*. Cranbrook, BC: UBCM Fuel Management Pilot Program. Retrieved from https://wfca.ca/wp-content/uploads/2018/06/Trembling-Aspen-Stands-as-Firebreaks_FINAL-REPORT.pdf

Guynn, D. C., Guynn, S. T., Wigley, T. B., & Miller, D. A. (2004). Herbicides and forest biodiversity: What do we know and where do we go from here? *Wildlife Society Bulletin, 32*(4), 1085–1092.

Hagner, M., Mikola, J., Saloniemi, I., Saikkonen, K., & Helander, M. (2019). Finnish ecological sustainability study: glyphosate-based Roundup herbicide has 'minor, transient' impacts on soil and animal health. *Scientific Reports 9*(1), 8540. doi.org/10.1038/s41598-019-44988-5

Haney, R. L., Senseman, S. A., & Hons, F. M. (2002). Effect of Roundup Ultra on microbial activity and biomass from selected soils. *Journal of Environmental Quality*, *31*(3), 730–735.

Harper, G. J. (2015). Lodgepole pine and trembling aspen mixedwoods: growth and yield within 22 to 39 year old pine plantations of northern interior British Columbia. *Forestry Chronicle, 91*(5), 502–518.

Harper, G. (2017). Lodgepole pine and trembling aspen competition: neighbourhood studies within 22 to 39 year old pine plantations of northern British Columbia. *Forestry Chronicle, 93*{3), 226–240. https:// doi .org/10.5558/tfc2017-031

Harper, G. J., Biring, B. C., & Heineman, J. (1997). *Mackay River herbicide trial: conifer response 9 years post-treatment* (Research Report 11). B.C. Ministry of Forest.

Harper, G. J., Comeau, P. G., & Biring, B. S. (2005). A comparison of herbicide and mulch mat treatments for reducing grass, herb, and shrub competition in the B.C. Interior Douglas-fir zone—ten-year results. *Western Journal of Applied Forestry, 20*(3), 167–176.

Harper, G., & Roach, J. (2014). *The role of broadleaf trees: impacts of managing boreal and sub-boreal mixedwood forests in British Columbia* (Extension Note 110). Victoria, BC: B.C. Ministry of Forests and Range.

Hart, D., & Comeau, P.G. (1992). *Manual brushing for forest vegetation management in British Columbia: a review of current knowledge and information needs* (Land Management Report 77). Victoria, BC: B.C. Ministry of Forests.

Hawkins, C. D. B., Dhar, A., & Lange, J. (2013). Vegetation management with glyphosate has little impact on understory species diversity or tree growth in a sub boreal spruce plantation—a case study. *Plant Biosystems, 147*(1), 105–114.

Heath, L. S., Kimble, J. M., Birdsey, R. A., & Lal, R. (2003). The potential of U.S. forest soils to sequester carbon. In J. M. Kimble, L. S. Heath, R. A. Birdsey, & R. Lal (Eds.). *The potential of U.S. forest soils to sequester carbon and mitigate the greenhouse effect* (385–394). Boca Raton: CRC Press.

Heineman, J. L., Simard, S. W., Sachs, D. L., & Mather, W. J. (2005). Chemical, grazing, and manual cutting treatments in mixed herb-shrub communities have no effect on interior spruce survival or growth in southern interior British Columbia. *Forest Ecology and Management, 205*(1–3), 359–374. https:// doi .org/10.1016/j. foreco.2004.10.038

Hjeljord, O., & Grønvold, S. (1988). Glyphosate application in forest—ecological aspects: VI. Browsing by moose (*Alces alces*) in relation to chemical and mechanical brush control. *Scandinavian Journal of Forest Research*, *3*(1–4), 115–121.

Houlahan, J. E., Findlay, C. S., Schmidt, B. R., Meyer, A. H., & Kuzmin, S. L. (2000). Quantitative evidence for global amphibian population declines. *Nature, 404*, 752–755.

Houston, A. P. C., Visser, S., & Lautenschlager, R. A. (2002). Response of microbial processes and fungal community structure to vegetation management in mixedwood forest soils. *Canadian Journal of Botany, 76*(12), 2002–2010.

Howe, C. M., Berrill, C. M., Pauli, B. D., Helbing, C. C., Werry, K., & Veldhoen, N. (2004). Toxicity of glyphosate-based pesticides to four North American frog species. *Environmental Toxicology and Chemistry, 23*, 1928–1938.

Kabzems R., & Harper, G. J. (2015). *Conifer and vegetation responses to pre-planting applications of glyphosate and hexazinone on a boreal backlog site, Sx trial 82502g-2* (Technical Report 087). Victoria, BC: Province of British Columbia. Retrieved from www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr087.htm

Kabzems, R., Nemec, A. L., & Farnden, C. (2007). Growing trembling aspen and white spruce intimate mixtures: early results (13–17 years) and future projections. *BC Journal of Ecosystems and Management, 8*(1), 1–14. Retrieved from http://www.forrex.org/publications/jem/ISS39/vol8 no1 artl.pdf

Kissane, Z., & Shephard, J. M. (2017). The rise of glyphosate and new opportunities for biosentinel early-warning studies. *Conservation Biology, 31*(6), 1293–1300.

Kuzyk, G., Marshall, S., Procter, C., Schindler, H., Schwantje, H., Gillingham, M., Hodder, D., White, S., & Mumma, M. (2018). *Determining factors affecting moose population change in British Columbia: testing the landscape change hypothesis. 2018 progress report: February 2012–April 2018* (Wildlife Working Report No. WR-126). Victoria, BC: B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Laatikainen, T., & Heinonen-Tanski, H. (2002). Mycorrhizal growth in pure cultures in the presence of pesticides. *Microbiological Research 157*(2), 127–137. doi: 10.1078/0944-5013-00139

Labbé, F., Lainesse, M., Nadeau, F-R., Prégent, G., & Savary, A. (2014). Analyse de rentabilité économique des plantations d'épinette noire et blanche et de pin gris. Bureau de mise en marché des bois, Québec (Québec). Retrieved from https://www.bmmb.gouv.qc.ca/analyses-economiques/

Laganiere, J., Boca, A., Van Miegroet, H., & Pare, D. (2017). A tree species effect on soil that is consistent across the species' range: the case of aspen and soil carbon in North America. *Forests, 8*, 113.

Lanctot, C., Navarro-Martin, L., Robertson, C., Park, B., Jackman, P., Pauli, B. D., & Trudeau, V. L. (2014). Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frog (*Lithobates sylvaticus*) tadpoles. II: Agriculturally relevant exposures to Roundup WeatherMax® and Vision® under laboratory conditions. *Aquatic Toxicology, 154*, 291–303.

Lanctot, C., Robertson, C., Navarro-Martin, L., Edge, C., Melvin, S. D., Houlahan, J., & Trudeau, V. L. (2013). Effects of the glyphosate-based herbicide Roundup WeatherMax® on metamorphosis of wood frogs (*Lithobates sylvaticus*) in natural wetlands. *Aquatic Toxicology, 140–141*, 48–57.

Lautenschlager, R. A. (1992). Effects of conifer release with herbicides on moose: browse production, habitat use, and residues in meat. *Alces, 28*, 215–222.

Lautenschager, R. A. (1993). Response of wildlife to forest herbicide applications in northern coniferous ecosystems. *Canadian Journal of Forest Research 23*, 2286–2299.

Lautenschlager, R. A., Dalton, W. J., Cherry, M. L., & Graham, J. L. (1999). Conifer release alternatives increase aspen forage quality in northwestern Ontario. *Journal of Wildlife Management, 63,* 1320–1326.

Lautenschlager, R. A., & Sullivan, T. P. (2002). Effects of herbicide treatments on biotic components in regenerating northern forests. *Forestry Chronicle,* 78, 1–37.

Legris, J., & Couture, G. (1991). Residus de Glyphosate dans le Gibier (Lievre, Orignal Qt cerf de Virginie) Suite a des Pulverisations en Milieu Forestier en 1988; Quebec Ministere des Forest, Direction de I' evaluation Environnementale: Charlesbourg, QC.

Lindgren, P. M. F., & Sullivan, T. P. (2001).Influence of alternative vegetation management treatments on conifer plantation attributes: abundance, species diversity, and structural diversity. *Forest Ecology and Management, 142*(1–3), 163–182.

Linz GM, Bleier WJ, Overland JD, Homan HJ. (1999). Response of invertebrates to glyphosate-induced habitat alterations in wetlands. *Wetlands,* 19, 220–227.

Macadam, A., & Kabzems, R. (2006). Vegetation management improves early growth of white spruce more than mechanical site preparation treatments. *Northern Journal of Applied Forestry*, 23(1), 35–46. https://doi.org/10.1093/njaf/23.1.35

McCulloch, L., & Kabzems, R. (2009). British Columbia's northeastern forests: aspen complex stand establishment decision aid. *BC Journal of Ecosystems and Management, 10*(2), 51–58. Retrieved from https://jem-online.org/index.php/jem/article/view/419

Meidinger, D. V., & Pojar, J. (1991). *Ecosystems of British Columbia* (Special Report Series 6). Victoria, BC: B.C. Ministry of Forests.

Mertens, M., Höss, S., Neumann, G., Afzal, J., & Reichenbecher, W. (2018). Glyphosate, a chelating agent—relevant for ecological risk assessment. *Environmental Science and Pollution Research, 25*(6), 5298–5317.

Mesnage, R., Defarge, N., De Vendômois, J.S., & Seralini, G.E. (2015). Potential toxic effects of glyphosate and its commercial formulations below regulatory limits. *Food and Chemical Toxicology, 84*, 133–153.

Mijangos, I., Becerril, J. M., Albizu, I., Epelde, L., & Garbisu, C. (2009). Effects of glyphosate on rhizosphere soil microbial communities under two different plant compositions by cultivation-dependent and-independent methodologies. *Soil Biology and Biochemistry*, *41*(3), 505–513.

Miller, D. T. (1985). Conifer release in the inland northwest – effects. In *Weed control for forest productivity in the interior west*. *Symposium Proceedings* (17–24). Spokane, WA: Washington State University.

Morgan, M. J., & Kiceniuk, J. W. (1992). Response of rainbow trout to a two month exposure to Vision®, a glyphosate herbicide. *Bulletin of Environmental Contamination and Toxicology, 48*, 772–780.

Munson, A. D., Margolis, H. A., & Brand, D. G. (1993). Intensive silvicultural treatment: impacts on soil fertility and planted conifer response. *Soil Science Society of America Journal*, *57*(1), 246–255.

Nabuurs, J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., Elsiddig, E., FordRobertson, J., Frumhoff, P., Karjalainen, T., Krankina, O., Kurz, W., Matsumoto, M., Oyhantcabal, W., Ravindranath, N., Sanz, M. Sanchez, T., & Zhang, X. (2007). Forestry. In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds). *Climate change 2007: mitigation*. Contribution of Working Group Ill to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Navarro-Martin, L., Lanctot, C., Jackman, P., Park, B. J., Doe, K., Pauli, B. D., & Trudeau, V. L. (2014). Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frogs (*Litho bates sylvaticus*) tadpoles. 1: Chronic laboratory exposures to Vision Max®. *Aquatic Toxicology, 154*, 278–290.

Navratil, S., Branter, K., & Zasada, J. (1991). Regeneration in the mixedwoods. In A. Shortreid (Ed.). *Proceedings of the Symposium on Northern Mixedwoods '89* (32–48). (FRDA Report 164). Victoria, BC: Forestry Canada, Pacific Forestry Centre.

Newsome, T. A., & Heineman, J. L. (2016). Adjusting free-growing guidance regarding aspen retention in the Cariboo-Chilcotin: research to operational implementation (Technical Report 102). Victoria, B.C: Province of British Columbia. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/TR102.htm

Newton, M., Cole, E. C., Lautenschlager, R. A., White, D. E., & McCormack, M. L., Jr. (1989). Browse availability after conifer release in Maine's spruce-fir forests. *Journal of Wildlife Management, 53*, 643–649.

Newton, M., Horner, L. M., Cowell, J. E., White, D. E., & Cole, E. C. (1994). Dissipation of glyphosate and aminomethylphosphonic acid in North American forests. *Journal of Agricultural and Food Chemistry, 42*(8), 1795–1802.

Newton, M., Howard, K. M., Kelpsas, B. R., Danhaus, R., Lottman, C. M., & Dubelman, S. (1984). Fate of glyphosate in an Oregon forest. *Journal of Agricultural and Food Chemistry, 32*,1144–1151.

Nicholson, J. (2007). *Survey of plantations established between 1998–2000 (6–8 years of age) on eastern Crown land without herbicides* (Forest Research Report 83). Nova Scotia Department of Natural Resources.

O'Hara, T. M., Carroll, G., Barboza, P., Mueller, K., Blake, J., Woshner, V., & Willetto, C. (2001). Mineral and heavy metal status as related to a mortality event and poor recruitment in a moose population in Alaska. *Journal of Wildlife Diseases, 37*(3), 509–522.

Ohtonen, R., Munson, A., & Brand, D. (1992). Soil microbial community response to silvicultural intervention in coniferous plantation ecosystems. *Ecological Applications*, *2*(4), 363–375.

Perala, D. A. (1985). *Using glyphosate herbicide in converting aspen to conifers* (Research Paper NC-259). St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.

Pesticide Management Regulatory Agency (PMRA). (2015). *Glyphosate revaluation decision RVD2015-1*. Health Canada.

Pesticide Management Regulatory Agency (PMRA). (2017). *Glyphosate revaluation decision RVD2017-1*. Health Canada.

Pesticide Management Regulatory Agency (PMRA). (2019). Statement from Health Canada on glyphosate. Health Canada. Retrieved from https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

Pitt, D. G., & Bell, F. W. (2005). Juvenile response to conifer release alternatives on aspen–white spruce boreal mixedwood sites. Part I: Stand structure and composition. *Forestry Chronicle, 81*(4), 538–547.

Pitt, D. G., Mihajlovich, M., & Proudfoot, L. M. (2004b). Juvenile stand responses and potential outcomes of conifer release efforts on Alberta's spruce aspen mixedwood sites. *Forestry Chronicle, 80*(5), 583–597.

Pitt, D. G., Wagner, R. G., & Towill, W. D. (2004a).Ten years of vegetation succession following ground-applied release treatments in young black spruce plantations. *Northern Journal of Applied Forestry 21*(3), 123–134.

Ratcliff, A. W., Busse, M. D., & Shestak, C.J. (2006). Changes in microbial community structure following herbicide (glyphosate) additions to forest soils. *Applied Soil Ecology*, *34*(2–3), 114–124.

Raymond, K. S., Servello, F. A., Griffith, B., & Eschholz, W. E. (1996). Winter foraging ecology of moose onglyphosate-treated clearcuts in Maine. *Journal of Wildlife Management, 60*, 753–763.

Reddy, K. N., Rimando, A. M., & Duke, S. O. (2004). Aminomethylphosphonic acid, a metabolite of glyphosate, causes injury in glyphosate-treated, glyphosate-resistant soybean. *Journal of Agricultural and Food Chemistry*, 52, 5139–5143.

Reynolds, P . E., Scrivener, J. C., Holtby, L. B., & Kingsbury, P. D. (1993). Review and synthesis of Carnation Creek herbicide research. *Forestry Chronicle, 69*(3), 323–330.

Rolando, C. A., Baillie, B. R., Thompson, D. G., & Little, K. M . (2017). The risks associated with glyphosate-based herbicide use in planted forests. *Forests, 8*(6), 208–233. Retrieved from https://www.mdpi.com/1999-4907/8/6/208

Rzymski, P., Klimaszyk, P., Kubacki, T., & Poniedziałek, B. (2013). The effect of glyphosate-based herbicide on aquatic organisms – a case study. *Limnological Review, 13*(4), 215–220.

Sanogo, S., Yang , X. B., & Scherm, H. (2000). Effects of herbicides on Fusarium solanif. sp. glycines and development of sudden death syndrome in glyphosate-tolerant soybean. *Phytopathology, 90*(1), 57–66. doi: 10.1094/PHYTO.2000.90.1.57

Santillo, D. J., Leslie, D. M., Jr., & Brown, P. W. (1989). Responses of small mammals and habitat to glyphosate application on clearcuts. *Journal of Wildlife Management, 53*, 164–172.

Shepperd, W. D., Rogers, P. C., Burton, D., & Bartos, D. L. (2006). *Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada* (General Technical Report RMRS-GTR-178). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Simard, S. (2001). *Effects of operational brushing on conifers and plant communities in the Southern Interior of British Columbia: results from PROBE 1991–2000, PRotocol for Operational Brushing* (Land Management Handbook 48). Victoria, BC: B.C. Ministry of Forests. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh48.pdf

Stratton, G.W. and Stewart, K.E., (1992). Glyphosate effects on microbial biomass in a coniferous forest soil. Environmental toxicology and water quality, 7(3), 223-236.

Sullivan, T.P., Wagner, R.G., Pitt, D.G., Lautenschlager, R.A., and Chen, D.G. (1998). Changes in diversity ofplant and small mammal communities after herbicide application in sub-boreal spruce forest. Canadian Journal of Forest Research, 28, 168–177.

Sullivan, T. P., & Sullivan, D. S. (2003). Vegetation management and ecosystem disturbance impact of glyphosate herbicide on plant and animal diversity in terrestrial ecosystems. *Environmental Review, 11*, 37–59.

Székács, A., & Darvas, B. (2012). Forty years with glyphosate. In M. N. A. E.-G. Hasaneen (Ed.). *Herbicides – properties, synthesis and control of weeds*. InTech: Rijeka, Croatia.

Tanney, J. B., & Hutchison, L. J. (2010). The effects of glyphosate on the in vitro linear growth of selected microfungi from a boreal forest soil. *Canadian Journal of Microbiology, 56*(2), 138–144.

Tarazona, J. V., Court-Marques, D., Tiramani, M., Reich, H., Pfeil, R., lstace, F., & Crivellente, F. (2017). Glyphosate toxicity and carcinogenicity: a review of the scientific basis of the European Union assessment and its differences with IARC. *Archives of Toxicology, 91*(8), 2723–2743.

Taylor, S. W., Pike, R. G., & Alexander, M. E. (1996). *Field guide to the Canadian forest fire behaviour prediction (FPB) system* (FRDA Handbook 012). Victoria, BC: Canadian Forest Service and B.C. Ministry of Forests. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/Docs/Frh/Frh012.pdf

Tesfamariam, T., Bott, S., Cakmak, I., Römheld, V., & Neumann, G. (2009). Glyphosate in the rhizosphere—role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants. *European Journal of Agronomy, 31*(3), 126–132.

Thiffault, N., & Roy, V. (2011). Living without herbicides in Québec (Canada): historical context, current strategy, research and challenges in forest vegetation management. *European Journal of Forest Research, 130*, 117–133. Retrieved from https://rd.springer.com/article/10.1007/s10342-010-0373-

Thompson, D., Leach, J., Noel, M., Odsen, S., & Mihajlovich, M. (2012). Aerial forest herbicide application: comparative assessment of risk mitigation strategies in Canada. *Forestry Chronicle, 88*(2), 176–184.

Thompson, D. G., & Pitt, D. G. (2011). *Frequently asked questions (FAQs) on the use of herbicides in Canadian forestry* (Frontline Technical Note 112). Canadian Forest Service, Great Lakes Forestry Centre.

Thompson, D. G., Pitt, D. G., Buscarini, T. M., Staznik, B., & Thomas, D. R. (2000). Comparative fate of glyphosate and triclopyr herbicides in the forest floor and mineral soil of an Acadian forest regeneration site. *Canadian Journal of Forest Research, 30*, 1808–1816.

Thompson, D. G., Pitt, D. G., Staznik, B., Payne, N. J., Jaipersaid, D., Lautenschlager, R. A., et al. (1997). On-target deposit and vertical distribution of aerially released herbicides. *Forestry Chronicle, 73*(1), 47–59.

Thompson, D. G, Wojtaszek, B. F., Staznik, B., Chartband, D. T., & Stephenson, R. (2004). Chemical and biomonitoring to assess potential acute effects of VisonR herbicide on native amphibian larvae in forest wetlands. *Environmental Toxicology and Chemistry, 23*, 843–849.

Vitousek, Peter & Andariese, Steven & Matson, Pamela & Morris, Lawrence & Sanford Jr, Robert. (1992). Effects of harvest intensity, site preparation, and herbicide use on soil nitrogen transformations in a young loblolly pine plantation. *Forest Ecology and Management*. 49. 277-292.

Wan, M. T. K. (1986). The persistence of glyphosate and its metabolite amino- methyl-phosphonic acid in somecoastal British Columbia streams. Regional Program Report 85-01. Dep. Environ., Environ. Prot. Serv., Vancouver, B.C

Wan, M. T., Watts, R. G. & Moul, D. J. (1989). Effects of different dilution water types on the acute toxicity to juvenile pacific salmonids and rainbow trout of glyphosate and its formulated products. *Bulletin of Environmental Contamination and Toxicology, 43*, 378–385. https://doi.org/10.1007/BF01701872

Wardle, D. A., & Parkinson, D. (1990). Influence of the herbicide glyphosate on soil microbial community structure. *Plant and Soil, 122*(1), 29–37.

Whitehead, R. J., & Harper, G. J. (1998). *A comparison of four treatments for weeding Engelmann spruce plantations in the Interior Cedar Hemlock Zone of British Columbia: ten years after treatment* (Information Report BC-X-379). Victoria, BC: Canadian Forest Service, Pacific Forestry Centre.

Wood, J. L. (2019). The presence of glyphosate in forest plants with different life strategies one year after application. *Canadian Journal of Forest Research, 49*(6), 586–594. https://doi.org/10.1139/cjfr-2018-0331

Wood, J. E., & von Althen, F. W. (1993). Establishment of white spruce and black spruce in boreal Ontario: effects of chemical site preparation and post-planting weed control. *Forestry Chronicle 69*, 554–560.

Zaller, J. G., Heigl, F., Ruess, L., & Grabmaier, A. (2014). Glyphosate herbicide affects belowground interactions between earthworms and symbiotic mycorrhizal fungi in a model ecosystem. *Scientific Reports, 4*, 5634.

APPENDIX 1. INTERNATIONAL ASSESSMENTS

Various international expert panels and regulators have reviewed glyphosate and its effect on human health. The consensus among national pesticide regulatory agencies and scientific organizations is that labelled uses of glyphosate have demonstrated no evidence of human carcinogenicity (Tarazona et al., 2017).

International Agency for Research on Cancer

In March 2015, the World Health Organization's International Agency for Research on Cancer (IARC), consisting of 17 experts from 11 countries, classified glyphosate as "probably carcinogenic in humans" based on epidemiological studies, animal studies, and in vitro studies.[9] This was based on "limited" evidence of cancer in humans (from exposures that actually occurred) and "sufficient" evidence of cancer in experimental animals (from studies of "pure" glyphosate). "Limited" evidence means that a positive association between exposure to the agent and cancer has been observed but that other explanations for the observations (called chance, bias, or confounding) could not be ruled out.

The International Agency for Research on Cancer also concluded that there was "strong" evidence for genotoxicity, both for "pure" glyphosate and for glyphosate formulations.[10]

European Food Safety Authority

In October 2015, the European Food Safety Authority of the European Union (EU) concluded that "the substance is unlikely to be genotoxic (i.e., damaging to DNA) or to pose a carcinogenic threat to humans."[11]

Glyphosate was not proposed to be classified as carcinogenic under the EU regulation for classification, labelling, and packaging of chemical substances. In particular, all the member state experts but one agreed that neither the epidemiological data (i.e., on humans) nor the evidence from animal studies demonstrated causality between exposure to glyphosate and the development of cancer in humans. A supplementary document clarified that while carcinogenic glyphosate-containing formulations may exist, studies "that look solely at the active substance glyphosate do not show this effect.[12]

Joint Food and Agriculture Organization of the United Nations/World Health Organization

The World Health Organization and Food and Agriculture Organization of the United Nations Joint Meeting on Pesticide Residues issued a report in 2016 stating that the use of glyphosate

9 https://www.iarc.fr/featured-news/media-centre-iarc-news-glyphosate/

10 https://monographs.iarc.fr/wp-content/uploads/2018/06/mono112-10.pdf

11 http://www.efsa.europa.eu/en/efsajournal/pub/4302

12 http://www.efsa.europa.eu/sites/default/files/4302_glyphosate_complementary.pdf

formulations does not necessarily constitute a health risk, and giving admissible daily maximum intake limits (1 mg/kg of body weight per day) for chronic toxicity.[13]

Environmental Protection Agency

In 2017, the U.S. Environmental Protection Agency classified glyphosate as "not likely to be carcinogenic to humans."[14] The Agency's assessment found no other meaningful risks to human health when the product is used according to the pesticide label.

European Chemicals Agency

In March 2017, the Committee for Risk Assessment of European Chemicals Agency concluded that the available scientific evidence did not meet the criteria to classify glyphosate as a carcinogen, as a mutagen, or as toxic for reproduction. However, it was classified as causing serious eye damage and being toxic to aquatic life, with long-lasting effects.[15]

Australian Pesticides and Veterinary Medicines Authority

In 2017, the Australian Pesticides and Veterinary Medicines Authority reviewed the IARC monograms and other international assessments and concluded that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.[16] The Agency provides a good online overview of various studies and issues, as well as an explanation of the IARC assessment.[17]

California

On July 7, 2017, in agreement with the IARC classification, California listed glyphosate as a known carcinogen under Proposition 65 law, which would require indicating this carcinogenicity hazard on the product label of glyphosate-based herbicide products. However, in response to a legal claim by an agricultural coalition that included the National Association of Wheat Growers, Monsanto Corporation, and farmer groups, the U.S. District Court issued a preliminary injunction against this evaluation on the basis that the classification by IARC claims glyphosate only probably carcinogenic, while apparently all other regulatory and governmental bodies found the opposite, including the U.S. Environmental Protection Agency.[18]

Canada

In 2015, Health Canada's Pest Management Regulatory Agency (PMRA) released a Proposed Re-evaluation Decision document on glyphosate. The consultation document described the registration process for the use of herbicides in Canada, a summary of the science evaluated, and the reasons for the proposed re-valuation decision. Input comments were solicited. The Agency re-evaluates pesticides on a recurring basis to ensure they meet modern health and environment safety standards and continue to have value. In April, 2017, Health Canada reapproved glyphosate. The Re-evaluation Decision document summarized the Agency's final decision on glyphosate, the reasons for it, and PMRA's response to comments received. An evaluation of the available scientific information found that products containing glyphosate do

13 https://www.who.int/foodsafety/areas_work/chemical-risks/JMPR_2016_Report_May.pdf

14 https://www.epa.gov/pesticides/epa-releases-draft-risk-assessments-glyphosate

15 https://echa.europa.eu/-/glyphosate-not-classified-as-a-carcinogen-by-echa

16 https://apvma.gov.au/sites/default/files/publication/26561-glyphosate-final-regulatory-position-report-final_0.pdf

17 https://apvma.gov.au/node/13891

18 https://www.frontiersin.org/articles/10.3389/fenvs.2018.00078/full

not present risks of concern to human health or the environment when used according to the revised label directions. As a requirement for the continued registration of glyphosate uses, new risk-reduction measures were required for end-use products registered in Canada. These included a restricted-entry period of 12 hours for agricultural uses, directions for application to minimize the potential for drift into areas of human activity, environmental hazard statements, spray buffer zones, precautionary statements, and use restrictions to reduce runoff into aquatic areas.

Following Health Canada's re-evaluation decision in 2017, eight notices of objection were received. There were also public concerns about the validity of the science as indicated in the so-called “Monsanto Papers”. On January 11, 2019, Health Canada issued a statement indicating that after a thorough scientific review, objections to glyphosate use could not be scientifically supported when considering the entire body of relevant data.

APPENDIX 2. STOCKING STANDARDS AND SURVEY CHANGES RELATED TO DECIDUOUS MANAGEMENT IN BRITISH COLUMBIA

2007: Recognizing the autecology of the competition species, specifically shrub and herb compared to broadleaf species (deciduous), and the effects of these specific competitors on managed coniferous stands.

2007: Using improved free-growing decision-making tools via the quadrant method to evaluate free growing and "potentially" free-growing trees at the plot level, considering:

• site series specific competition thresholds

• competition thresholds specific to the silvics of managed crop species

This is a more refined evaluation method in the Coast, North, and South regions compared to simply evaluating competition within a 1-m cylinder with standard crop-to-brush ratios, as used in the past.

2009: Employing regionally developed brush competition assessments, specific to many BEC variants in the three Cariboo Timber Supply Areas, based on empirical data collected by silviculture researchers. This neighbourhood concept has led to a greater flexibility in crop trees being assessed as free growing when intermixed and overtopped by broadleaf competition. As well, in certain BEC variants in the Cariboo, broad leaf competition is considered as "non-deleterious", which does not affect their status as free growing.

2011: Developing new broadleaf forest health free-growing damage criteria, used to assess the acceptability of broad-leaves as free growing, given these deciduous species are specified as crop trees in an approved Forest Stewardship Plan.

2018: Expanding the "non-deleterious" definition of broadleaf competition, in conifer managed stands, to all site series within the IDFdk4 and SBPSxc BEC variants within the three Cariboo Timber Supply Areas.

APPENDIX 3. INTEGRATED PEST MANAGEMENT PRINCIPLES

Elements of Integrated Pest Management include:

1. prevention;

2. pest identification;

3. seedling and vegetation monitoring;

4. injury thresholds and treatment decisions;

5. treatment options and selection criteria; and

6. post-treatment effectiveness evaluation.

Environmental protection strategies and procedures

Prevention

Prevention of vegetation competition issues can be achieved through the following:

- **Site preparation:** The intent of site preparation is to reduce the impacts of growth-limiting factors that might inhibit seedling establishment or growth potential.
- **Planting:** Stock with high genetic worth can improve survival performance of planted seedlings. Similarly, large seedling stock is better suited to compete for light and can withstand higher brush hazards.
- **Species selection:** Species selection is based on the ecological suitability of a species to the specific site conditions in an area. Additional considerations include immediate and long-term forest health factors, future forest products, volume and value, climate change, and consistency with the Timber Supply Analysis.
- **Regeneration delay:** Seedlings that are quickly established are more likely to compete successfully with problematic vegetation. Especially on brush-prone sites, seedlings should be planted as soon as possible following harvesting.
- **Microsite selection:** Seedlings that are planted in the best microsite possible and that remain undamaged during the planting process are more likely to compete successfully with problematic vegetation.
- **Fertilization:** Fertilization treatments can improve seedling establishment and reduce the need for brushing.
- **Advanced regeneration**: Another stand establishment option is to utilize advanced growth in the understory at the time of harvesting. This could involve partial cuts such as shelterwood silviculture systems where silvics and site conditions are appropriate.

Pest identification

In the context of vegetation management, the term "pest" refers to herbaceous, shrub, and broadleaf complexes or communities that:

- inhibit plantation establishment;
- hinder optimal growth and development of crop trees;
- prevent a stand from achieving free growing;
- affect an established plantation's overall health; or
- when combined with snow, causes damage to crop trees by snow press.

Identification of potential vegetation problems starts with sound ecosystem classification from which vegetation complexes can be predicted. Post-harvest assessments and seedling monitoring can also help in identifying potential or realized brush problems.

Seedling and vegetation monitoring

Surveys and walk-throughs are scheduled throughout the plantations' development in order to ensure that stocking and brush levels are acceptable and that free-growing parameters will be achieved within the appropriate time frame. Monitoring includes post-harvest assessments, regeneration delay surveys, regeneration performance walk-throughs, and free-growing surveys.

Injury thresholds and treatment decisions

Decisions to control vegetation on a site may be based on a number of different protocols depending on regional and ecological parameters. Measures such as competition index (CI) and height-to-diameter ratio may be used to determine whether competing vegetation is negatively impacting crop trees. Crop tree status and vigour may also be evaluated based on local knowledge or percentage of crop trees that are overtopped, threatened, or above the brush.

Competition index measures competition for sunlight with regards to crop trees. It is calculated as the sum of the products of cover and height for all non-crop species within a 1.26-m radius around a crop tree, divided by crop-seedling height, and shows that growth declines with increases in the index. There is a very rapid decline in growth as CI increases from 0 to 100. At CI = 100, growth is approximately 60% of that of a seedling growing free from competition. At a CI = 150, seedlings receive 30% of the full sunlight in midsummer and would achieve approximately 45% of potential growth rates (Comeau et al., 1993). Treatment may be recommended when CI > 80.

Height-to-diameter ratio (HDR) of crop trees can indicate sturdiness. In low light conditions, conifers will put more resources toward height growth, which makes them susceptible to vegetation and snow press. Treatment may be recommended with HDR > 40 or 50, depending on species, where > 50% of stems exceed the HDR.

Treatment options

Aerial application

Broadcast treatment using a helicopter equipped with a low-pressure boom and high-volume nozzles. Variable application rates are possible. May control brush for 2–4 years.

Discretionary, non-continuous application across portions of the block can also be applied.

The most cost-effective treatment and the safest option for workers on the ground

Benefits	Limitations
• Effective control for a number of years • Minimal worker contact with chemicals • Low cost • Can treat remote, steep, slashy ground more safely than alternatives • Can treat large areas in a short time	• Less selective than other methods • Stringent application constraints • Intensive preparation and follow-up • High public profile • Residual leave trees are obstacles • Visual quality affected for years • Technically demanding • Drift can occur outside treatment areas

Backpack application

Backpack broadcast—continuous application across treatment unit with low-pressure backpack sprayer with adjustable nozzles. Variable application rates are possible. May control brush for 2–4 years. Discretionary non-continuous or spot treatment can be applied.

Benefits	Limitations
• Effective control for a number of years • Can treat blocks with standing residuals • Selective. Can apply with precision • Only small buffers needed in pesticide-free zones	• Stringent application constraints • Intensive preparation and follow-up • Requires high level of supervision • Exposure of workers to herbicide • Safety concerns about wearing heavy equipment on rough terrain • Access and water availability • Constrained by brush height • Inconsistent results from dew, rainfall, and missed spots that are difficult to detect during monitoring • Safety concerns about evacuating from remote sites • Crew availability

Cut stump

Selective application of herbicide onto a cut stump of target vegetation. Brush saw or power saw cuts the stump, and a worker applies herbicide using a backpack sprayer, squeeze bottle, or nozzle mounted on the saw. May control brush for approximately 4 years.

Benefits	Limitations
• Effective control for a number of years • Longer treatment window • Little worker exposure to herbicide • Only small buffers needed in pesticide-free zones • Low application rate	• Stringent application constraints • Intensive preparation and follow-up • Requires high level of supervision • Some exposure of workers to herbicide • Safety hazards operating power saws • Safety concerns about wearing heavy equipment on rough terrain

Motor-manual

Workers cut target vegetation with power saws or brush saws. May control herbaceous brush for less than 1 year, deciduous brush for about 2 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatments
• Public acceptance	• Safety hazards operating power saws
• Can be applied selectively	• Expensive treatment cost
• Can be used in pesticide-free zone buffers	• Relatively short window for treatment
• Not effective on herbaceous brush	• Limited availability of workers
	• Slash loads can be fire hazards, limit trafficability

Hand tools

Workers treat spots around crop trees with handheld cutters.

Girdling hardwoods to remove a continuous strip of bark around the circumference, which kills trees 2–3 years later.

Snap/hinge—partially breaking smaller stems by hand.

May control brush for less than 1 year. Girdling can control brush for about 3 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatments
• Public acceptance	• Expensive treatment cost
• Can be applied selectively	• Repetitive strain injuries are common
• Can be used in pesticide-free zone buffers	• Limited availability of workers
	• Girdling not effective on herbaceous brush

Sheep grazing

Shepherds guide a flock of sheep (1000–1500) through treatment areas, where they eat target vegetation. May control brush for 1 year.

Benefits	Limitations
• No herbicide use	• Expensive treatment cost
• Not constrained by weather	• Some crop tree damage
• Safe for workers	• Herbaceous, limited height
	• Need good access, gentle terrain, low slash.

- Risk of disease to wildlife
- Risk from predators

Mechanical site preparation

Mechanically creating favourable planting spots that mitigate limiting site factors such as cold, poorly aerated soils, competing vegetation, and frost risk. Where brush hazards are high, mounding is preferred so seedlings are elevated and receive more light, and vegetation falls away from crop trees rather than presses over them. Mounding is done with excavators or implements attached to prime movers such as skidders. May control brush for 3–5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Public acceptance	• Access and soil disturbance
• Increased soil temperature	• Site constraints—trafficability
• Facilitates planting	• Availability of contractors in the north

Prescribed burning

Prescribed burning is another form of site preparation that uses ground crews or a helicopter to apply a controlled burn. May control brush for 3–5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Good seedbed, plantable spots	• Liability and risk of escape
	• Smoke and health effects
	• Risks to workers

Treatment selection

Treatment methods for a specific site will be selected based on a number of factors, including safety concerns, timing, treatment efficacy, cost, biophysical constraints, legal constraints, political constraints, and concerns from other users and stakeholders. The following lists some of these factors:

- **Target species height**: Backpack treatments cannot be sprayed overhead. Sheep are also constrained by their ability to reach foliage and are restricted to sites with vegetation less than 1 m in height.
- **Target species diameter**: Girdling is impractical at diameters of less than 3 cm or greater than 10 cm.
- **Target species distribution**: Broadcast foliar treatments are not effective if target species are in clumps. Discretionary treatments are less appropriate if the target brush is evenly distributed.
- **Physical impediments to treatment**: Aerial treatments can be limited by residual trees, or small, irregular shaped treatment units. Ground-based treatments can be affected by steep slopes, uneven terrain, slash loading, difficult access, and remote access.

- **Buffers**: Blocks with many features that require no-treatment zones and pesticide-free zones, such as water bodies, wetlands, and roads, may have little area for herbicide treatments once all the buffers are established.
- **Timing**: Chemical treatment windows are small and require conifers that are hardening off to avoid chemical damage while target species are still succulent. Motor-manual treatment windows may overlap with fire seasons and are dependent on fire risk safety measures.
- **Special wildlife features**: Heavy browsing might reduce the need for brushing if there is little alternative browse available. Treatments that create heavy slash loads that restrict game movement may be avoided. Sheep grazing may be a poor choice in grizzly bear high-use areas.
- **Vulnerable plant species**: Vulnerable plant species are defined as those plants whose numbers are either limited or are important for browse or forage. Vulnerable plant species must be protected from broadcast treatments where identified.
- **First Nations rights infringement**: When specific information indicates that there is a higher likelihood of treatments infringing on First Nations rights on a unit, certain treatments may be considered unsuitable, or modified. For example, if consultation with a First Nation indicated that a specific site is used for berry-picking, a broadcast chemical treatment would be considered inappropriate.
- **Potential for conflict**: Some proposed treatments may result in an unacceptable risk of conflict with the public, First Nations, or other stakeholders.
- **Potential for crop tree damage**: Heavy slash loading from motor-manual treatments could mechanically damage crop trees. It can be difficult to spot crop trees in dense vegetation, which can result crop tree damage. Brushing can increase the risk of root rot spreading. Slash loading or dead stems can also create fire risks.
- **Availability of crews**: It is increasingly difficult to attract workers to the silviculture industry, and brushing is onerous physical work. Safety is also a factor, as higher numbers of injury claims are associated with higher claim payments for brushing and weeding. Fewer people are engaging in this sector. The area manually brushed, 11,600 ha in 2018, would have to double to treat the sprayed area, so workforce availability would be limiting.

Post-treatment effectiveness evaluation

Efficacy is checked for the amount of target vegetation removed, current level of competition, missed areas, crop tree damage, environmental impacts, and scheduling of next entry.

Environmental protection strategies and procedures

Operational procedures and standards for herbicide applications (including herbicide transportation, storing, mixing, loading, disposal) and the environmental safeguards in place regarding herbicide field application, including considerations regarding:

- strategies to protect community watersheds and other domestic water sources
- strategies to protect fish and wildlife, riparian areas, and wildlife habitat
- pesticide-free zones
- species at risk

- strategies to prevent herbicide treatment of food intended for human consumption
- pre-treatment inspection procedures for identifying treatment area boundaries
- weather monitoring and strategies
- procedures for maintaining and calibrating herbicide application equipment

GLOSSARY

BEC	Biogeoclimatic Ecosystem Classification
FLNRORD	B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FPPR	Forest Planning and Practices Regulation
FSP	Forest Stewardship Plan
IPMR	Integrated Pest Management Regulation
PMP	Pest Management Plan
PMRA	Health Canada Pest Management Regulatory Agency
RESULTS	Reporting Silviculture Updates and Land Status Tracking System
sph	stems per hectare



info@fpinnovations.ca
www.fpinnovations.ca

OUR OFFICES

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
(514) 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
(604) 224-3221

Québec
1055 rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
(418) 659-2647

BRIEFING NOTE FOR INFORMATION

DATE: December 11, 2019

PREPARED FOR: Diane Nicholls, Assistant Deputy Minister, Chief Forester, Minister of Forests, Lands, Natural Resource Operations and Rural Development

ISSUE: Summary of FPInnovations Glyphosate Review Report

BACKGROUND:

- Glyphosate is an herbicide used by the forest sector to reduce broadleaf competition with conifer plantations in order to accelerate the attainment of free-to-grow status.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was awarded a $75,000[1] consulting services contract to assess current peer reviewed forest science and best practices related to glyphosate use in the context of, but not necessarily limited to:
    - The current value-set that applies to forest management throughout BC;
    - Where and why forest managers use glyphosate, how it relates to the current value-set (e.g., carbon, First Nations (FN), wildlife, and wildlife habitat, and alternative vegetation management approaches;
    - Document the uncertainties and assumptions related to forestry-related glyphosate use; and
    - How glyphosate use supports the overarching objective of promoting the establishment of healthy and diverse forests.
- This note provides a summary of highlights, key findings and recommendations set out in FPI's report. Subsequent notes will address potential next steps, including internal and external communication.

HIGHLIGHTS, KEY FINDINGS AND RECOMMENDATIONS:

<u>General/Background</u>

- Glyphosate-based herbicides are the most widely used in the world due to their cost, effectiveness and safety.
- The effects of glyphosate on human health have been extensively reviewed by international regulatory agencies, including Health Canada, with the conclusion generally being that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.

s.13

[1] Subsequently increased to $82,500.

s.13

Regulation and Use

- Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada. The PRMA re-approved glyphosate for use in Canada in 2017. After objections were raised regarding the re-approval the PRMA issued a supplementary statement in which it concluded that the objections could not be scientifically supported.
- The BC Ministry of Environment and Climate Change (ENV) regulates the sale and use of pesticides in BC under the Integrated Pest Management Act. Large scale use of pesticides requires the proponent to prepare and adhere to a Pest Management Plan.
- Notwithstanding its effectiveness as a silvicultural tool, glyphosate is also used to help manage invasive species. Of the 1,593 ha treated with herbicides for control of invasive species under the BC provincial jurisdictions of highways, forests and parks agencies in 2018, 8% of the area was treated using glyphosate.
- Data from this ministry's RESULTS shows that:
    - Roughly 11,000 ha of Crown land was treated with glyphosate in 2018 with 86% sprayed aerially and 14% sprayed via ground-based methods;
    - Most of the spraying of glyphosate occurred in the Omineca Natural Resource Region (73%) followed by the Northeast Region (11%); and
    - Smaller amounts of glyphosate use also occurred in the Thompson-Okanagan and South Coast Regions.
- The area sprayed has declined from an average of 13,802 ha for the last five years and higher historical levels. The area sprayed in 2018 was 0.044% of the 25 M ha available for harvesting in BC and 0.44% of the tenured area on crown land that has an outstanding reforestation obligation.
- The proportion of area harvested that has had any kind of vegetation control treatment has decreased from 18% to 14% over the last 10 years.
- In contrast to agriculture and other common land uses where areas are sprayed repeatedly, glyphosate in forestry is typically applied once or occasionally twice in a rotation.
- Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species, but are most commonly used in the Sub-Boreal Spruce biogeoclimatic zone targeting trembling aspen, mixed shrub, fireweed and wet alder.

Treatment Costs

- Glyphosate treatment costs vary widely, but are typically at least half that of manual methods (e.g., $300-$500/ha vs. $700-$1,200/ha). The differential cost of using manual methods vs.

glyphosate for silviculture is currently estimated to $15 M/yr based upon 11,000 ha treated provincially exclusive of timber productivity loses.

Biodiversity

- One of the primary public concerns regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broadleaves are being eliminated from the landscape. These claims are not supported when analysing the level of deciduous components at free-growing, or the increase in mixed deciduous stands over time as a result of forest management.
- A 2008 review of species diversity pre and post-harvest in BC found that the amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods. Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing, a 3,000% increase. Analysis further suggests that aspen stocking recovers after glyphosate spraying and may in fact be increasing over time with forest management activities.
- Studies found that species richness and diversity of nontarget vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies also found that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment. In many cases, herbaceous vegetation abundance, diversity and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank. Further, while glyphosate tends to result in a larger initial reduction of a wider range of species, brushing alternatives such as manual brushing has similar effects on plant communities, albeit at a higher treatment cost.
- Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least 1 year. Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality, however some translocation into shoots and fruit was observed in select plants.

Aquatic Organisms

- Amphibian populations are declining around the world and chemical contaminants released to aquatic environments have been listed as a threat. Studies have shown direct effects of chronic glyphosate exposures on fish, amphibians, invertebrates and other components of the ecosystem. However, field studies have not been able to replicate these toxicity effects under typical glyphosate application rates and conditions. Further, numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development, the expression of genes related to larval development, or juvenile amphibian survival. This is likely due to the short exposure duration and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands.
- A field study in coastal BC found temporary stress effects and minor mortality in caged Coho salmon smolt post glyphosate application. However, no acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident Coho. Similarly, no effects on growth, behaviour or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment.

While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations in BC mandate the use of no-treatment pesticide-free zones around water features, dry streams and classified wetlands, further reducing the risk of negative effects on aquatic ecosystems.

Wildlife

- Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates. However, some uncertainty remains regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage.
- Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline.
- Glyphosate treatment has been found to reduce wildlife forage availability in the short term, reducing moose use of glyphosate-treated area for the first few years after treatment. However, the long-term impact of glyphosate use on habitat selection by moose is not well understood. Further, some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls although these impacts must also be considered in relation to the area treated annually and its distribution over the landscape. The effects of glyphosate's chelating[2] properties on forage quality and nutrient availability are also poorly understood.

Soil and Water Quality

- Glyphosate is largely immobilized in the soil and then dissipates via microbial degradation. One of the compounds released during the microbial breakdown process – AMPA – is adsorbed to soils and biodegraded. However, AMPA is considered to be a mild phytotoxin with relatively unknown long-term consequences on soil organisms and plants.
- The mandated use of no-treatment pesticide-free zones around water features, the strong sorption to upper soil layers and the rapid uptake by plants minimize the risk of glyphosate entering aquatic ecosystems. Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken.

Climate Change

- Vegetation management can affect carbon sequestration due to its impact on structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows the establishment of a woody crop delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools. When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species.

Wildfire

[2] Chelation is a type of bonding of ions and molecules to metal ions. It involves the formation or presence of two or more separate coordinate bonds between a polydentate ligand and a single central atom. These ligands are called chelants, chelators, chelating agents, or sequestering agents.

- Fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires.
- The Canadian Forest Fire Behaviour Prediction system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous or leaf-on mixed wood stands.
- Amongst deciduous trees, poplars show the most fire resistance. In one study, researchers estimate broadleaf forests to remain next to inflammable even as drought conditions worsen, in stark contrast to coniferous forests.
- The effect of fire behaviour from deciduous vegetation treated with glyphosate is not well documented. It is expected that the fire hazard in treated dead stems following treatment either manually or chemically would be very high.

First Nations

- Some FNs across BC have expressed concern over the use of glyphosate in forests related to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated.

Public Use

- Forest managers are faced with mounting public pressure over the safety of glyphosate use.
- Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping or hiking. The PMRA's review on glyphosate has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health.
- There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues.
- Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue.
- Better communication of the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, between forest managers and recreational users can help address key public concerns.

Timber Supply

- Vegetation control in some cases is necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests.
- Glyphosate is cost-effective vs. manual vegetation control methods.
- Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked area with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

Conclusions

s.13

-

- A review of current inventory data shows that stands that have been treated with glyphosate retain 15-21% deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.
- Field studies have shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.
- Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.
- While more research is recommended on the identified knowledge gaps, the use of glyphosate needs to be further considered within the context of the amount of area treated, the short time scale of site-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels. Many of the public's concerns and challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by better linkages between site and landscape level planning that allow other non-timber values to be prioritized where needed.

Recommendations

s.13

s.13

Attachments: Review of Glyphosate Use in BC Forestry (FPI, Dec. 11, 2019).

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
ADM	DN	
ED	SB	
Program Dir/Mgr.	SH	

Begon, Stacey FLNR:EX

From: Hedges, Shawn FLNR:EX
Sent: December 12, 2019 8:58 AM
To: Berg, Shane FLNR:EX; Psyllakis, Jennifer FLNR:EX; Bedford, Lorne FLNR:EX; MacDougall, Julie FLNR:EX; Hughes, Neil FLNR:EX; Gordon, Steve M FLNR:EX; Mullan, Jonathan M ENV:EX; Zacharias-Homer, Christa ENV:EX
Cc: sitkaforestry@shaw.ca
Subject: Re: Final FPI and BN
Attachments: 252256 ADM BNI - Summary of FPI Glyphosate Review Report (Dec 12_19).docx

Colleagues, FYI only…attached is a slightly edited version of the BN reflecting some late suggested edits from Jennifer.

SH

From: Shawn Hedges
Date: Wednesday, December 11, 2019 at 3:09 PM
To: "Berg, Shane FLNR:EX" , "Psyllakis, Jennifer FLNR:EX" , "Bedford, Lorne FLNR:EX" , "MacDougall, Julie FLNR:EX" , "Hughes, Neil FLNR:EX" , "Gordon, Steve M FLNR:EX" , "Mullan, Jonathan M ENV:EX" , "Zacharias-Homer, Christa ENV:EX"
Cc: "sitkaforestry@shaw.ca"
Subject: Final FPI and BN

Colleagues, attached is the final glyphosate report I received earlier today from FPI. Also attached is a finalised briefing note for our Chief Forester. I'll be moving both forward later today via eApprovals.

I'll likely put pen to paper soon and start writing a second, shorter BC for our minister and senior executive providing them with a summary of what the report says and proposed next steps. I'll run this past the group when I've got something stable that I'm happy with.

_____
Shawn Hedges, RPF
Director, Sustainability & Forestry
Office of the Chief Forester
Forests, Lands, Natural Resource Operations & Rural Development
Cellular (250) 896-9911

Ministry of Forests, Lands, Natural Resource Operations and Rural Development

CLIFF: 252256
X-REF: 250351

BRIEFING NOTE FOR INFORMATION

DATE: December 12, 2019

PREPARED FOR: Diane Nicholls, Assistant Deputy Minister, Chief Forester, Minister of Forests, Lands, Natural Resource Operations and Rural Development

ISSUE: Summary of FPInnovations Glyphosate Review Report

BACKGROUND:

- Glyphosate is an herbicide used by the forest sector to reduce broadleaf competition with conifer plantations in order to accelerate the attainment of free-to-grow status.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was awarded a $75,000[1] consulting services contract to assess current peer reviewed forest science and best practices related to glyphosate use in the context of, but not necessarily limited to:
    - The current value-set that applies to forest management throughout BC;
    - Where and why forest managers use glyphosate, how it relates to the current value-set (e.g., carbon, First Nations (FN), wildlife, and wildlife habitat, and alternative vegetation management approaches;
    - Document the uncertainties and assumptions related to forestry-related glyphosate use; and
    - How glyphosate use supports the overarching objective of promoting the establishment of healthy and diverse forests.
- This note provides a summary of highlights, key findings and recommendations set out in FPI's report. Subsequent notes will address potential next steps, including internal and external communication.

HIGHLIGHTS, KEY FINDINGS AND RECOMMENDATIONS:

General/Background

- Glyphosate-based herbicides are the most widely used in the world due to their cost, effectiveness and safety.
- The effects of glyphosate on human health have been extensively reviewed by international regulatory agencies, including Health Canada, with the conclusion generally being that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.
- Several factors can be considered to inform s.13 the use of glyphosate in forestry applications in BC including:
    - Effective and ~~Targeted~~ targeted vegetation control s.13 to achieve plantation survival and achievement of free growing objective s.13 s.13 i.e., sustainable timber supply);

[1] Subsequently increased to $82,500.

- Cost-effectiveness relative to alternative treatment options;
- Ability to s.13 control re-sprouting of perennial competitive vegetation;
- Persistence in the natural environment through time s.13 (Nb. biodegradation s.13 s.13 s.13 profile appears to vary in different ecosystem types);
- s.13
- s.13 Toxicity to non-target flora and fauna in surrounding environment s.13 and
- s.13 Potential trade-offs across non-timber objectives.

Regulation and Use

- Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada. The PRMA re-approved glyphosate for use in Canada in 2017. After objections were raised regarding the re-approval the PRMA issued a supplementary statement in which it concluded that the objections could not be scientifically supported.
- The BC Ministry of Environment and Climate Change (ENV) regulates the sale and use of pesticides in BC under the Integrated Pest Management Act. Large scale use of pesticides requires the proponent to prepare and adhere to a Pest Management Plan.
- Notwithstanding its effectiveness as a silvicultural tool, glyphosate is also used to help manage invasive species. Of the 1,593 ha treated with herbicides for control of invasive species under the BC provincial jurisdictions of highways, forests and parks agencies in 2018, 8% of the area was treated using glyphosate.
- Data from this ministry's RESULTS shows that:
  - Roughly 11,000 ha of Crown land was treated with glyphosate in 2018 with 86% sprayed aerially and 14% sprayed via ground-based methods;
  - Most of the spraying of glyphosate occurred in the Omineca Natural Resource Region (73%) followed by the Northeast Region (11%); and
  - Smaller amounts of glyphosate use also occurred in the Thompson-Okanagan and South Coast Regions.
- The reasons for the high use of aerial application in the Omineca Region was not explicitly reviewed.

Formatted: Font color: Text 1, English (Canada)

- The area sprayed has declined from an average of 13,802 ha for the last five years and higher historical levels. The area sprayed in 2018 was 0.044% of the 25 M ha available for harvesting in BC and 0.44% of the tenured area on crown land that has an outstanding reforestation obligation.
- The proportion of area harvested that has had any kind of vegetation control treatment has decreased from 18% to 14% over the last 10 years.
- In contrast to agriculture and other common land uses where areas are sprayed repeatedly, glyphosate in forestry is typically applied once or occasionally twice in a rotation.
- Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species, but are most commonly

used in the Sub-Boreal Spruce biogeoclimatic zone targeting trembling aspen, mixed shrub, fireweed and wet alder.

Treatment Costs

- Glyphosate treatment costs vary widely, but are typically at least half that of manual methods (e.g., $300-$500/ha vs. $700-$1,200/ha). The differential cost of using manual methods vs. glyphosate for silviculture is currently estimated to $15 M/yr based upon 11,000 ha treated provincially exclusive of timber productivity loses.

Biodiversity

- One of the primary public concerns regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broadleaves are being eliminated from the landscape. These claims are not supported when analysing the level of deciduous components at free-growing, or the increase in mixed deciduous stands over time as a result of forest management.
- A 2008 review of species diversity pre and post-harvest in BC found that the amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods. Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing, a 3,000% increase. Analysis further suggests that aspen stocking recovers after glyphosate spraying and may in fact be increasing over time with forest management activities.
- Studies found that species richness and diversity of nontarget vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies also found that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment. In many cases, herbaceous vegetation abundance, diversity and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank. Further, while glyphosate tends to result in a larger initial reduction of a wider range of species, brushing alternatives such as manual brushing has similar effects on plant communities, albeit at a higher treatment cost.
- Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least 1 year. Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality, however some translocation into shoots and fruit was observed in select plants.

Aquatic Organisms

- Amphibian populations are declining around the world and chemical contaminants released to aquatic environments have been listed as a threat. Studies have shown direct effects of chronic glyphosate exposures on fish, amphibians, invertebrates and other components of the ecosystem. However, field studies have not been able to replicate these toxicity effects under typical glyphosate application rates and conditions. Further, numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development, the expression of genes related to larval development, or juvenile amphibian

survival. This is likely due to the short exposure duration and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands.

- A field study in coastal BC found temporary stress effects and minor mortality in caged Coho salmon smolt post glyphosate application. However, no acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident Coho. Similarly, no effects on growth, behaviour or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment. While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations in BC mandate the use of no-treatment pesticide-free zones around water features, dry streams and classified wetlands, further reducing the risk of negative effects on aquatic ecosystems.

Wildlife

- Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates. However, some uncertainty remains regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage.
- Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline.
- Glyphosate treatment has been found to reduce wildlife forage availability in the short term, reducing moose use of glyphosate-treated area for the first few years after treatment. However, the long-term impact of glyphosate use on habitat selection by moose is not well understood. Further, some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls although these impacts must also be considered in relation to the area treated annually and its distribution over the landscape. The effects of glyphosate's chelating[2] properties on forage quality and nutrient availability are also poorly understood.

Soil and Water Quality

- Glyphosate is largely immobilized in the soil and then dissipates via microbial degradation. One of the compounds released during the microbial breakdown process – AMPA – is adsorbed to soils and biodegraded. However, AMPA is considered to be a mild phytotoxin with relatively unknown long-term consequences on soil organisms and plants.
- The mandated use of no-treatment pesticide-free zones around water features, the strong sorption to upper soil layers and the rapid uptake by plants minimize the risk of glyphosate entering aquatic ecosystems. Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken.

Climate Change

- Vegetation management can affect carbon sequestration due to its impact on structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows

[2] Chelation is a type of bonding of ions and molecules to metal ions. It involves the formation or presence of two or more separate coordinate bonds between a polydentate ligand and a single central atom. These ligands are called chelants, chelators, chelating agents, or sequestering agents.

the establishment of a woody crop delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools. When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species.

Wildfire

- Fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires.
- The Canadian Forest Fire Behaviour Prediction system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous or leaf-on mixed wood stands.
- Amongst deciduous trees, poplars show the most fire resistance. In one study, researchers estimate broadleaf forests to remain next to inflammable even as drought conditions worsen, in stark contrast to coniferous forests.
- The effect of fire behaviour from deciduous vegetation treated with glyphosate is not well documented. It is expected that the fire hazard in treated dead stems following treatment either manually or chemically would be very high.

First Nations

- Some FNs across BC have expressed concern over the use of glyphosate in forests related to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated.

Public Use

- Forest managers are faced with mounting public pressure over the safety of glyphosate use.
- Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping or hiking. The PMRA's review on glyphosate has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health.
- There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues.
- Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue.
- Better communication of the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, between forest managers and recreational users can help address key public concerns.

Timber Supply

- Vegetation control in some cases is necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests.
- Glyphosate is cost-effective vs. manual vegetation control methods.

- Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked area with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

Conclusions

- Glyphosate is one of s.13 a number of vegetation management tools available to forest managers and is the most cost-effective way to manage competing vegetation to promote. s.13 s.13 plantation survival, and to meet free growing obligations that to ensure stand productivity and a sustainable timber supply into the future.
- A review of current inventory data shows that stands that have been treated with glyphosate retain 15-21% deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.
- Field studies have shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.
- Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.
- While more research is recommended on the identified knowledge gaps, the use of glyphosate needs to be further considered within the context of the amount of area treated, the short time scale of site-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels. Many of the public's concerns and challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by better linkages between site and landscape level planning that allow other non-timber values to be prioritized where needed.

Recommendations

s.13

s.13

Attachments: Review of Glyphosate Use in BC Forestry (FPI, Dec. 11, 2019).

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
ADM	DN	
ED	SB	
Program Dir/Mgr.	SH	

Begon, Stacey FLNR:EX

From: Hedges, Shawn FLNR:EX
Sent: December 13, 2019 1:55 PM
To: Berg, Shane FLNR:EX; Psyllakis, Jennifer FLNR:EX; Bedford, Lorne FLNR:EX; MacDougall, Julie FLNR:EX; Hughes, Neil FLNR:EX; Gordon, Steve M FLNR:EX; Mullan, Jonathan M ENV:EX; Zacharias-Homer, Christa ENV:EX; Uppenborn, Jeremy GCPE:EX
Cc: sitkaforestry@shaw.ca; Haslam, David GCPE:EX
Subject: Re: Draft glyphosate BN for Minister Donaldson
Attachments: 252744 MDD BNI - FPI Glyphosate Review Report (Dec 13_19).docx

Colleagues, attached is a redlined version of the MDD BN that reflects recent input from Shane and Steve.

I'm going to clean this version up, put it in eApps and move it along to the minister via normal approval protocols.

s.22

Shawn

From: Shawn Hedges
Date: Thursday, December 12, 2019 at 1:48 PM
To: "Berg, Shane FLNR:EX" , "Psyllakis, Jennifer FLNR:EX" , "Bedford, Lorne FLNR:EX" , "MacDougall, Julie FLNR:EX" , "Hughes, Neil FLNR:EX" , "Gordon, Steve M FLNR:EX" , "Mullan, Jonathan M ENV:EX" , "Zacharias-Homer, Christa ENV:EX" , "Uppenborn, Jeremy GCPE:EX"
Cc: "sitkaforestry@shaw.ca" , "Haslam, David GCPE:EX"
Subject: Draft glyphosate BN for Minister Donaldson

Colleagues, as promised below, attached is short, draft BN for Minister Donaldson. I would appreciate it if you could take a few minutes to review it and provide me with your comments before I start a long Christmas break at the end of day tomorrow.

Thanks.

Shawn

From: Shawn Hedges
Date: Thursday, December 12, 2019 at 8:58 AM
To: "Berg, Shane FLNR:EX" , "Psyllakis, Jennifer FLNR:EX" , "Bedford, Lorne FLNR:EX" , "MacDougall, Julie FLNR:EX" , "Hughes, Neil FLNR:EX" , "Gordon, Steve M FLNR:EX" , "Mullan, Jonathan M ENV:EX" , "Zacharias-Homer, Christa ENV:EX"
Cc: "sitkaforestry@shaw.ca"
Subject: Re: Final FPI and BN

Colleagues, FYI only…attached is a slightly edited version of the BN reflecting some late suggested edits from Jennifer.

SH

From: Shawn Hedges
Date: Wednesday, December 11, 2019 at 3:09 PM
To: "Berg, Shane FLNR:EX" , "Psyllakis, Jennifer FLNR:EX" , "Bedford, Lorne FLNR:EX" , "MacDougall, Julie FLNR:EX" , "Hughes, Neil FLNR:EX" , "Gordon, Steve M FLNR:EX" , "Mullan, Jonathan M ENV:EX" , "Zacharias-Homer, Christa ENV:EX"
Cc: "sitkaforestry@shaw.ca"
Subject: Final FPI and BN

Colleagues, attached is the final glyphosate report I received earlier today from FPI. Also attached is a finalised briefing note for our Chief Forester. I'll be moving both forward later today via eApprovals.

I'll likely put pen to paper soon and start writing a second, shorter BC for our minister and senior executive providing them with a summary of what the report says and proposed next steps. I'll run this past the group when I've got something stable that I'm happy with.

_____

Shawn Hedges, RPF
Director, Sustainability & Forestry
Office of the Chief Forester
Forests, Lands, Natural Resource Operations & Rural Development
Cellular (250) 896-9911

Ministry of Forests, Lands, Natural Resource Operations and Rural Development

CLIFF: 252744
X-REF: 252256

BRIEFING NOTE FOR INFORMATION

DATE: December 12, 2019

PREPARED FOR: Honourable Doug Donaldson, Minister of Forests, Lands, Natural Resource Operations and Rural Development

ISSUE: FPInnovations Glyphosate Review Report

BACKGROUND:

- Glyphosate is a~~n~~ herbicide used by foreste~~r~~ managers to reduce broadleaf competition ~~with~~ of conifer plantations ~~in order~~ to accelerate the attainment of free-to-grow status.
- Glyphosate use is a controversial issue with the public, particularly related to recent declines in moose populations.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee comprised of staff from Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) and Environment and Climate Change (ENV) was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was awarded a consulting services contract to assess current peer reviewed forest science and best practices related to glyphosate use primarily in the context of the current value-set that applies to forest management throughout B.C. (e.g., biodiversity, First Nations, climate change, soil and water, etc.).
- This note provides a brief summary of FPI's report~~. As well, the note~~ and sets out next steps, including internal and external communication.

DISCUSSION:

- Based on an initial assessment of the ~50-page report (ref. Appendix 1), FPI reports that the risk of glyphosate and its metabolites[1] on the environment is minimal when the herbicide is applied according to the product instructions (~~label~~). Further, it confirms ~~and~~ that species richness and diversity of flora and fauna remain in the range of natural variation, and that any change~~s~~ to these communities when glyphosate is used is transient.
- Glyphosate ~~—~~is one of many vegetation management tools available to forest managers. ~~—is~~Glyphosate, while very cost-effective, ~~is declining in use, and its use is limited and declining~~ relative to the forested area harvested each year. In 2018, ~ 11,000 hectares of Crown land in B.C. were treated with glyphosate representing 7% of the Crown area harvested that year, most of which was in the Omineca Forest Region.
- Further, the FPI ~~reports~~ report also indicates that contrary to current public perceptions, the data indicates that parts of B.C. have shown a significant increase in mixed deciduous stands over the years due to previous harvesting activity; even in stands that have been previously treated with glyphosate. Deciduous trees still account for 15-20% of the stems per hectare at free growing.

[1] A metabolite refers to the product that remains after a chemical has broken down, digested or otherwise processed.

Formatted: Font color: Auto, English (United Kingdom)

Draft

- The FPI report also makes a series of recommendations related to opportunities to improve research and data; particularly with respect to glyphosate persistence in plants, impact on soil micro-organisms, wildlife forage and fire behaviour.
- ~~Lastly,~~ The FPI report also includes ~~poses some~~ recommendations related to the opportunities to improve 2-way communication with First Nations and the public related to glyphosate use.

NEXT STEPS:

s.13

Formatted: Font: Italic

Attachments:

1. Briefing note "*Summary of FPInnovations Glyphosate Review Report*" (CLIFF 252256).
2. Review of Glyphosate Use in BC Forestry (FPI, Dec. 11, 2019).

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
ADM	DN	
ED	SB	
Program Dir/Mgr.	SH	

Begon, Stacey FLNR:EX

From: Hedges, Shawn FLNR:EX
Sent: January 6, 2020 2:00 PM
To: Mullan, Jonathan M ENV:EX; Zacharias-Homer, Christa ENV:EX; Bedford, Lorne FLNR:EX; Berg, Shane FLNR:EX; Psyllakis, Jennifer FLNR:EX; Gordon, Steve M FLNR:EX; Hughes, Neil FLNR:EX; MacDougall, Julie FLNR:EX
Subject: FW: Glyphosate question
Attachments: 252744 MDD BNI - FPI Glyphosate Review Report.pdf; 252744 ATT 2 - FPInnovations - Glyphosate Use in BC Forestry - Final 20191211.pdf; 252256 ATT 1 - ADM BNI - Summary of FPI Glyphosate Review Report.pdf

Glyphosate steering committee, FYI, attached is a copy of the finalized briefing note and attachments sent to Minister Donaldson just before the Christmas break.

In terms of the agenda for today's call at 3 pm, I propose the following:

1) We need a new file lead to take over from me in 2 weeks s.22
2) We need to discuss key next steps re: this file. For example:
    a. Complete a detailed FLNRORD/ENV review of the report and communicate findings to key senior government staff (by whom and by when?)
    b. Develop a joint action plan for MDD by June 2020 describing key actions re: policy and research.
    c. In consultation with GCPE, develop an Issues Note and Key Messages document for use with respect to enquiries about the report. Also need to firm up approach for how and when to release copies of the FPI report on an as-requested basis and what sort of messaging we may want to accompany release.
3) Lastly, I would appreciate your thoughts on the request from Ken Byrne below re: sharing copies of the FPI report with FPI members.

Shawn

From: Ken Byrne
Date: Friday, December 13, 2019 at 2:46 PM
To: Shawn Hedges
Subject: Glyphosate question

Hi Shawn,

Nice to chat with you today. I think our computer connections got cut right at the last sentence there but in case you missed it I wish you all the best over the holidays.

As I mentioned, we are beginning to get more interest from our Members about information on the use of herbicides. I know that our report is fresh in your hands and it will take some time to review, digest and decide how action any of the findings so I respect all the time you will need for that before considering how the results will be released.

If and when you do decide can you please let me know when and to what degree we can share the results in the report with our Members? Whether that be the full report, a redacted version or a summary of results, I will let you all at the Ministry decide.

Again, thank you very much for the opportunity to work on this with you.

All the best,
Ken

KEN BYRNE, RPF, Ph.D.
Manager, Forest Operations
Gestionnaire, Opérations forestières

FPInnovations
2665 East Mall, Vancouver, BC, Canada V6T 1Z4
T 604-222-5709 | **C** 604-831-5332

BRIEFING NOTE FOR INFORMATION

DATE:	December 12, 2019
PREPARED FOR:	Diane Nicholls, Assistant Deputy Minister, Chief Forester, Minister of Forests, Lands, Natural Resource Operations and Rural Development
ISSUE:	Summary of FPInnovations Glyphosate Review Report

BACKGROUND:

- Glyphosate is an herbicide used by the forest sector to reduce broadleaf competition with conifer plantations in order to assist in the achievement of free-to-grow status.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was awarded a $75,000[1] consulting services contract to assess current peer-reviewed forest science and best practices related to glyphosate use in the context of, but not necessarily limited to:
    - The current value-set that applies to forest management throughout BC;
    - Where and why forest managers use glyphosate, how it relates to the current value-set e.g., carbon, First Nations (FN), wildlife, and wildlife habitat, and alternative vegetation management approaches;
    - Document the uncertainties and assumptions related to forestry-related glyphosate use; and
    - How glyphosate use supports the overarching objective of promoting the establishment of healthy and diverse forests.
- This note provides a summary of highlights, key findings and recommendations set out in FPI's report. Subsequent notes will address potential next steps, including internal and external communication.

HIGHLIGHTS, KEY FINDINGS AND RECOMMENDATIONS:

<u>General/Background</u>

- Glyphosate-based herbicides are the most widely used in the world due to their cost, effectiveness, and safety.
- The effects of glyphosate on human health have been extensively reviewed by international regulatory agencies, including Health Canada, with the conclusion generally being that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.
- Several factors can be considered to inform the use of glyphosate in forestry applications in BC, including:
    - Effective and targeted vegetation control to achieve plantation survival and achievement of the free growing objective (i.e., sustainable timber supply);

[1] Subsequently increased to $82,500.

- Cost-effectiveness relative to alternative treatment options;
- Ability to control resprouting of perennial competitive vegetation;
- Persistence in the natural environment through time (NB. biodegradation profile appears to vary in different ecosystem types);
- Toxicity to non-target flora and fauna in surrounding environment; and
- Potential trade-offs across non-timber objectives.

Regulation and Use

- Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada. The PRMA re-approved glyphosate for use in Canada in 2017. After objections were raised regarding the re-approval, the PRMA issued a supplementary statement in which it concluded that the objections could not be scientifically supported.
- The BC Ministry of Environment and Climate Change (ENV) regulates the sale and use of pesticides in BC under the *Integrated Pest Management Act*. Large scale use of pesticides requires the proponent to prepare and adhere to a Pest Management Plan.
- Notwithstanding its effectiveness as a silvicultural tool, glyphosate is also used to help manage invasive species. Of the 1,593 hectares treated with herbicides for control of invasive species under the BC provincial jurisdictions of highways, forests, and parks agencies in 2018, 8 percent of the area was treated using glyphosate.
- Data from this ministry's RESULTS application program shows that:
  - Roughly 11,000 hectares of Crown land was treated with glyphosate in 2018 with 86 percent sprayed aerially and 14 percent sprayed via ground-based methods;
  - Most of the spraying of glyphosate occurred in the Omineca Natural Resource Region (73 percent) followed by the Northeast Region (11 percent); and
  - Smaller amounts of glyphosate use also occurred in the Thompson-Okanagan and South Coast Regions.
  - The reasons for the high use of aerial application in the Omineca Region were not explicitly reviewed.
- The area sprayed has declined from an average of 13,802 hectares for the last five years and higher historical levels. The area sprayed in 2018 was 0.044 percent of the 25 million hectares available for harvesting in BC, and 0.44 percent of the tenured area on Crown land that has an outstanding reforestation obligation.
- The proportion of area harvested that has had any kind of vegetation control treatment has decreased from 18 percent to 14 percent over the last 10 years.
- In contrast to agriculture and other common land uses where areas are sprayed repeatedly, glyphosate in forestry is typically applied once or occasionally twice in a rotation.
- Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species, but are most commonly used in the Sub-Boreal Spruce biogeoclimatic zone targeting trembling aspen, mixed shrub, fireweed, and wet alder.

Treatment Costs

- Glyphosate treatment costs vary widely but are typically at least half that of manual methods (e.g., $300-$500/hectare vs. $700-$1,200/hectare). The differential cost of using manual methods vs. glyphosate for silviculture is currently estimated to $15 million/year based upon 11,000 hectares treated provincially exclusive of timber productivity losses.

Biodiversity

- One of the primary public concerns regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broadleaves are being eliminated from the landscape. These claims are not supported when analysing the level of deciduous components at free-growing, or the increase in mixed deciduous stands over time as a result of forest management.
- A 2008 review of species diversity pre- and post-harvest in BC found that the amount of deciduous mixed stands at free growing increased from 2,811 hectares before harvest to 55,614 hectares in the Northern Interior Forest Region for all reporting periods. Similarly, in the Southern Interior Forest Region, deciduous mixed stands increased from 1,202 hectares before harvest to 37,268 hectares at free growing, a 3,000 percent increase. Analysis further suggests that aspen stocking recovers after glyphosate spraying and may in fact be increasing over time with forest management activities.
- Studies found that species richness and diversity of non-target vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies also found that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment. In many cases, herbaceous vegetation abundance, diversity, and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank. Further, while glyphosate tends to result in a larger initial reduction of a wider range of species, brushing alternatives such as manual brushing has similar effects on plant communities, albeit at a higher treatment cost.
- Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions due to the phytotoxicity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least one year. Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality; however, some translocation into shoots and fruit was observed in select plants.

Aquatic Organisms

- Amphibian populations are declining around the world and chemical contaminants released to aquatic environments have been listed as a threat. Studies have shown direct effects of chronic glyphosate exposures on fish, amphibians, invertebrates, and other components of the ecosystem. However, field studies have not been able to replicate these toxicity effects under typical glyphosate application rates and conditions. Further, numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development, the expression of genes related to larval development, or juvenile amphibian survival. This is likely due to the short exposure duration and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands.
- A field study in coastal BC found temporary stress effects and minor mortality in caged Coho salmon smolt post glyphosate application. However, no acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident Coho.

Similarly, no effects on growth, behaviour, or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment. While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations in BC mandate the use of no-treatment pesticide-free zones around water features, dry streams, and classified wetlands, further reducing the risk of negative effects on aquatic ecosystems.

Wildlife

- Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates. However, some uncertainty remains regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage.
- Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline.
- Glyphosate treatment has been found to reduce wildlife forage availability in the short term, reducing moose use of glyphosate-treated area for the first few years after treatment. However, the long-term impact of glyphosate use on habitat selection by moose is not well understood. Further, some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls, although these impacts must also be considered in relation to the area treated annually and its distribution over the landscape. The effects of glyphosate's chelating[2] properties on forage quality and nutrient availability are also poorly understood.

Soil and Water Quality

- Glyphosate is largely immobilized in the soil and then dissipates via microbial degradation. One of the compounds released during the microbial breakdown process – AMPA – is adsorbed to soils and biodegraded. However, AMPA is considered to be a mild phytotoxin with relatively unknown long-term consequences on soil organisms and plants.
- The mandated use of no-treatment pesticide-free zones around water features, the strong sorption to upper soil layers, and the rapid uptake by plants minimize the risk of glyphosate entering aquatic ecosystems. Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken.

Climate Change

- Vegetation management can affect carbon sequestration due to its impact on structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows the establishment of a woody crop, delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools. When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species.

[2] Chelation is a type of bonding of ions and molecules to metal ions. It involves the formation or presence of two or more separate coordinate bonds between a polydentate ligand and a single central atom. These ligands are called chelants, chelators, chelating agents, or sequestering agents.

Wildfire

- Fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires.
- The Canadian Forest Fire Behaviour Prediction system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous or leaf-on mixed wood stands.
- Amongst deciduous trees, poplars show the most fire resistance. In one study, researchers estimate broadleaf forests to remain next to inflammable even as drought conditions worsen, in stark contrast to coniferous forests.
- The effect of fire behaviour from deciduous vegetation treated with glyphosate is not well documented. It is expected that the fire hazard in treated dead stems following treatment either manually or chemically would be very high.

First Nations

- Some FNs across BC have expressed concern over the use of glyphosate in forests related to plants that are traditionally gathered for food or medicinal purposes, and which are killed directly by glyphosate or are considered contaminated.

Public Use

- Forest managers are faced with mounting public pressure over the safety of glyphosate use.
- Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping or hiking. The PMRA's review on glyphosate has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health.
- There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues.
- Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue.
- Better communication of the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, between forest managers and recreational users, can help address key public concerns.

Timber Supply

- Vegetation control in some cases is necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term, and the economic benefit derived from forests.
- Glyphosate is cost-effective vs. manual vegetation control methods.
- Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked area with

direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

Conclusions

- Glyphosate is one of a number of vegetation management tools available to forest managers and is the most cost-effective way to manage competing vegetation to promote plantation survival, meet free growing obligations to ensure stand productivity and a sustainable timber supply into the future.
- A review of current inventory data shows that stands that have been treated with glyphosate retain 15-21 percent deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.
- Field studies have shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds, and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.
- Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.
- While more research is recommended on the identified knowledge gaps, the use of glyphosate needs to be further considered within the context of the amount of area treated, the short time scale of site-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels. Many of the public's concerns and challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by better linkages between site and landscape level planning that allow other non-timber values to be prioritized where needed.

Recommendations

s.13

s.13

Attachments: Review of Glyphosate Use in BC Forestry (FPI, Dec. 11, 2019).

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
ADM	DN	December 19, 2019
ED	SB	December 16, 2019
Program Dir/Mgr.	SH	December 12, 2019

FPInnovations

info@fpinnovations.ca
www.fpinnovations.ca

REVIEW OF GLYPHOSATE USE IN BRITISH COLUMBIA FORESTRY

PROJECT NUMBER: 301013763

Jim Hunt, Lead Scientist

Pamela Matute, Researcher

November 2019

FPInnovations

October 2019

The present is a review of current glyphosate use in British Columbia forestry, peer-reviewed forest science on the impacts of glyphosate use on forests, and input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in British Columbia was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishing forest stands post-harvest.

Project number: 301013763

ACKNOWLEDGEMENTS

This project was contracted by the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development

REVIEWERS
Ken Byrne, Manager, Fibre Supply

AUTHOR CONTACT INFORMATION
Pamela Matute
Researcher, Fibre Supply
pamela.matute@fpinnovations.ca
(604) 222-5698

APPROVER CONTACT INFORMATION
Shawn Hedges
Director, Sustainability and Forestry

shawn.hedges@gov.bc.ca

Disclaimer to any person or entity as to the accuracy, correctness, or completeness of the information, data, or any analysis thereof contained in this report, or any other recommendation, representation, or warranty whatsoever concerning this report.

Follow us

Table of contents

Executive Summary 1
1 Introduction 3
2 Use of Glyphosate in British Columbia Forests 4
2.1 Regulatory Framework 4
2.1.1 Free Growing 4
2.1.2 Herbicides 5
2.2 Why is Glyphosate Used? 6
2.2.1 Site Preparation 7
2.2.2 Plantation Survival 7
2.2.3 Crop Tree Productivity 7
2.2.4 Invasive Species 7
2.3 How is Glyphosate Used? 8
2.3.1 Area Treated 8
2.3.2 Glyphosate Use at the Stand Level 11
2.4 Treatment Costs 13
3 Impact of glyphosate use on non-timber values 14
3.1 Biodiversity 14
3.1.1 Broadleaf Tree Species 14
3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide treatment 14
3.1.1.2 RESULTS analyses 15
3.1.2 Non-Target Plant Communities 16
3.1.3 Aquatic Organisms 17
3.1.4 Wildlife 18
3.1.4.1 Toxicity 18
3.1.4.1 Forage quality and quantity 18
3.2 Soil and Water Quality 19
3.2.1 Glyphosate/aminomethylphosphonic acid fate in soils 19
3.2.2 Soil microorganisms 20
3.2.3 Glyphosate/aminomethylphosphonic acid fate in water 20
3.3 Climate Change 21

3.4 Wildfire 21
3.5 First Nations 22
3.6 Public Use 23
4 Impacts on Timber Supply 24
4.1 Managing for Multiple Values 25
5 Recommendations 26
6 Conclusions 27
7 References 28
Appendix 1. International Assessments 40
Appendix 2. Stocking Standards and Survey Changes Related to Deciduous Management in British Columbia 43
Appendix 3. Integrated Pest Management Principles 44
Glossary 51

EXECUTIVE SUMMARY

FPInnovations was contracted by the Office of the Chief Forester to undertake a review of current glyphosate use in British Columbia (B.C.) forestry including peer-reviewed forest science on the impacts of glyphosate use on forests, and input from stakeholders. The use of glyphosate in relation to the multiple values that are pertinent to forest management in B.C. was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishing forest stands post-harvest. The report will inform future policy development and research needs, with the main objective to promote the establishment of healthy and diverse forests.

The herbicide glyphosate is one of many vegetation management tools available to forest managers. As a tool for vegetation control, it is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. It is very effective because it is easily translocated within the target plant, and usually kills it and reduces the brush hazard for multiple years after a single application, unlike other motor-manual vegetation control methods. Glyphosate application may target aggressive competition from broad-leaved trees, shrubs, and herbaceous vegetation.

In 2018, approximately 11,000 ha of Crown land in B.C. were treated with glyphosate for silvicultural purposes. The total area treated with glyphosate was 7% of the area harvested on B.C. Crown land in 2018, and less than 0.5% of the area with outstanding reforestation obligations. In 2018, most (73%) of the glyphosate application was conducted in the Omineca Natural Resource Region. Of all the biogeoclimatic zones, the Sub-Boreal Spruce zone received the most glyphosate application (76%). Glyphosate was applied primarily aerially (86%); the remainder (14%) was applied using ground-based methods.

Public concerns over the impacts of glyphosate use on the ecosystem are growing, particularly regarding ecosystem changes resulting from the control of broadleaf trees such as trembling aspen. A RESULTS (Reporting Silviculture Updates and Land Status Tracking System) analysis of deciduous stand components at free growing showed that in the Omineca Natural Resource Region, where most of the glyphosate application occurs, deciduous components accounted for 15–21% of the stand density on sites that were previously treated with glyphosate. Data also show that in the B.C. Interior, mixed deciduous stands have been increasing over time as a result of forest management activities.

A summary of the many studies on the impact of glyphosate on forest soils, water, non-target plant communities, and wildlife is presented. While impacts can vary with site characteristics, research has shown that the risk of glyphosate and its metabolites on the environment is minimal when the herbicide is applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes to these communities are related to changes in vegetation structure and are transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects of glyphosate on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. Recent research has found low but unexpected levels of glyphosate residue in plants 1 year following treatment, which may have implications for wildlife forage quality, plant physiology, and

traditional food and medicine plant harvesting. While residue levels were non-toxic to humans and wildlife, little is known about their persistence and their effect on forage quality and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

Glyphosate remains an important tool for establishing conifer or conifer–deciduous mixed stands and ensuring future timber supply. Glyphosate bans in other jurisdictions in Canada have resulted in significant struggles to meet silvicultural objectives on the land base, which highlights glyphosate's important role in maintaining conifer productivity. Forest management in B.C. seeks to balance all values ascribed to the forest, with the overarching objective of establishing and maintaining healthy and diverse forests. While more research on the identified knowledge gaps is recommended, glyphosate needs to be considered in the context of these values and objectives, and with perspective regarding the amount of area treated, the apparent transient effects on the site's ecology, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels.

1 INTRODUCTION

Public pressure to reduce the use of glyphosate has been increasing in British Columbia (B.C.) and other jurisdictions. In response, the Office of the Chief Forester for the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) contracted FPInnovations to undertake a review of current peer-reviewed forest science and best practices on glyphosate use in B.C. forestry. Input from stakeholders was also solicited. The forestry use of glyphosate in relation to the multiple values pertinent to forest management in B.C. was considered. The report will inform future policy development and research needs, with the main objective to promote the establishment of healthy and diverse forests.

Successful regeneration of forests after timber harvesting often requires control of competing vegetation, which may cause mortality or reduced growth of established seedlings. Several vegetation management alternatives exist for this purpose, including chemical (e.g., glyphosate, triclopyr) and non-chemical (e.g., manual cutting, girdling, sheep grazing) methods.

Glyphosate-based herbicides are the most widely used in the world, largely due to their effectiveness, their safety for non-target species and the environment, and the development of glyphosate-tolerant agricultural crops. Several factors support the use of this herbicide in forestry applications in B.C.:

- ability to translocate within treated plants and control resprouting of perennial weeds;
- generally favourable environmental profile, including binding in soils and rapid biodegradation in most soils, water, and sediments;
- specific mechanism of action, inhibiting an enzyme found in plants;
- low toxicity to animals; and
- minimal impact on forest ecosystems (Rolando et al., 2017).

This report focuses on glyphosate application for silviculture as a vegetation management tool in re-establishing forest stands post-harvest. The use of glyphosate for agriculture, transmission or transportation corridors, or other industrial uses is outside the scope of this report. The effects of glyphosate on human health and the environment have been extensively reviewed by regulatory agencies (Appendix 1), including by Health Canada's Pest Management Regulatory Agency as recently as 2017 and again in 2019. These findings are summarized in Appendix 1.

2 USE OF GLYPHOSATE IN BRITISH COLUMBIA FORESTS

2.1 Regulatory Framework

2.1.1 Free Growing

In B.C., timber harvesting in public forests is regulated such that any harvested area must be reforested to an acceptable standard of free growing. The *Forest Range and Practices Act* (sec 1) defines "free growing" as "a stand of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees". A free-growing stand is expected to contribute to landscape objectives and to a sustainable long-term fibre supply.

The Forest Planning and Practices Regulation (FPPR) (sec 44) addresses obligations to produce a free-growing stand that meets applicable stocking standards approved in a Forest Stewardship Plan (FSP) by specified dates. Stocking standards are regulatory tools that ensure that the re-establishment of a forest stand post-harvest is aligned to large-scale objectives for the land base as set out in FSPs. Stocking standards specify regeneration requirements such as suitable tree species for the site, stand density, spacing, free-growing height, and ratio of crop tree height to surrounding competing vegetation.

Sec 46.11 of the FPPR indicates that these silvicultural obligations must be fulfilled on each hectare within the net area to be reforested, unless otherwise specified in an FSP. Mappable areas that do not meet stocking standards should not exceed 2 ha or 5% of the Standards Unit area. Under the FPPR (sec 97.1), an obligation holder may be relieved of the obligation to meet stocking standards if they can prove that obligations have been met to the extent that is practicable.

Sec 26 (5) of the FPPR also provides a mechanism for developing stocking standards in an FSP that are not consistent with current timber supply assumptions. The review test for sec 26 (5) requires the delegated decision maker to be satisfied that the regeneration date and stocking standards are reasonable, having regard for future timber supply and the set values ascribed to forest land.

Free-growing surveys are the tool that forest managers use to measure whether a stand meets free-growing obligations. Survey methods, including quantification of shrub and broadleaf competition, are described in the Silviculture Surveys Procedures Manual.

Stocking standards and related guidance have evolved since the 1990s and continue to evolve to incorporate current understanding of resource issues (e.g., broadleaf species) and their impact on timber supply and other forest values. A summary of these developments is described in Appendix 2.

2.1.2 Herbicides

Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada to ensure that pesticides pose minimal risk to human health and the environment. Under authority of the *Pest Control Products Act*, Health Canada:

- registers pesticides after a stringent, science-based evaluation that ensures any risks are acceptable;
- re-evaluates the pesticides currently on the market on a 15-year cycle to ensure the products meet current scientific standards; and
- promotes sustainable pest management.

The latest PMRA re-evaluations of glyphosate safety were conducted in 2017 and then again shortly after in 2019 (PMRA 2017, 2019). Following the release of the re-approval decision in 2017, Health Canada received eight notices of objection that questioned the validity of the re-evaluation after revelations that several scientific publications may not have followed due scientific process in what came to be called the Monsanto Papers. After a scientific review of these claims and the publications in question, the PMRA issued a statement in January 2019 indicating that the objections did not cast doubt on the original 2017 decision, and that glyphosate remains approved for use in Canada (PMRA, 2019).

The *Integrated Pest Management Act* and Regulation (IPMR) sets out the requirements for the use and sale of pesticides in B.C. The B.C. Ministry of the Environment and Climate Change Strategy promotes Integrated Pest Management and environmental stewardship and ensures compliance with the *Integrated Pest Management Act* and Regulation. Large-scale pesticide programs (i.e., > 20 hectares per year of treatment area) that require Integrated Pest Management must have a confirmed Pest Management Plan (PMP). These plans document how the standards set in the IPMR will be implemented regarding environmental protection, notification, and herbicide handling and application, as well as alternatives to using herbicides. The content of PMPs is detailed in Appendix 3.

Integrated Pest Management is a process for managing pest populations. In a forestry context where competing vegetation is considered as a pest or weed, the following integrated vegetation management elements would apply:

- planning and managing ecosystems to prevent organisms from becoming weeds;
- identifying weed problems and potential weed problems;
- monitoring weed populations and weed complexes;
- using injury thresholds, levels at which pest numbers are high enough to cause unacceptable injury or damage, in making treatment decisions;
- selecting pest treatment methods based on:
    - consideration of practical alternatives to herbicide use,
    - protection of human health and the environment; and

- evaluating the effectiveness of weed management treatments.

Herbicides are rarely the only integrated vegetation management method used and are generally used in conjunction with other methods. Examples of best practices for implementing integrated vegetation management are included in Appendix 3.

2.2 Why is Glyphosate Used?

Managing competing vegetation is an essential part of reforestation efforts after forest harvesting. In B.C., vegetation management focuses on highly aggressive herbaceous complexes such as fireweed or bluejoint grass, and competitive deciduous trees such as red alder and trembling aspen. Targeted vegetation control is used in silviculture for two main reasons:

- to maintain plantation survival; and
- to meet free-growing obligations that ensure stand productivity and sustainable future timber supply.

Glyphosate is one of many chemical and non-chemical vegetation management tools available to forest managers (see Appendix 3 for other vegetation management alternatives). It may be applied aerially or with ground-based methods such as backpack sprayer, hack and squirt, cut stump, and vehicle-mounted sprayer. In recent years, backpack spraying has been the most common ground-based treatment used, while broadcast boom spraying with helicopters is the only aerial method used.

The primary benefit of using glyphosate is its effectiveness in controlling competing vegetation. Because it is easily translocated within the target plant, killing it outright, it can reduce the brush hazard for multiple years after a single application, as opposed to manual methods, which do not kill root systems and may result in re-sprouting of perennial weeds or stimulation of suckering by trembling aspen. Manual vegetation control treatments typically provide only short-term relief from competing vegetation, with control often lasting only for the balance of the growing season in which the treatment was applied (Miller 1985; Hart and Comeau 1992; Comeau et al., 1999, 2000). Several studies have found that a single manual treatment may be ineffective for sufficiently controlling cover to benefit seedling growth for more than a few years (Ehrentraut and Brantner 1990; Harper et al., 1997; 1998; Whitehead and Harper 1998; Comeau et al., 1999, 2000; Simard 2001; Heineman et al., 2005). The main manual methods used to control competing vegetation are brush saws, manual cutting, and power saws. Other methods such as girdling, sheep grazing, and stem bending using hockey sticks are used on a smaller scale due to their logistical difficulties and high cost.

The need for multiple treatments when relying on manual treatments, the higher cost associated with them, the increased safety risk to manual brushing workers, and the limited availability of brushing crews have helped make glyphosate a popular vegetation control alternative. No single vegetation control method suits all sites, however. Logistical, environmental, and safety concerns affect the choice of vegetation management. BC Timber Sales (BCTS) and licensees with reforestation obligations document when and how herbicides and other vegetation control methods are used in their Pest Management Plans (see Appendix 3).

Depending on the developmental stage of a plantation and its brush complex, glyphosate may be used to clear a planting site of pre-established brush, to reduce seedling competition in order to ensure plantation survival, or to meet free-growing requirements that ensure long-term productivity and timber supply, particularly where management is focused on specific timber species and outcomes.

2.2.1 Site Preparation

Glyphosate is sometimes used to prepare a site for planting where highly competitive vegetation complexes have become established prior to planting. Vegetation control before planting is preferred where it is expected that vegetation will impact plantable spots, target planting density, and plantation survival and growth. The average annual area of sites prepared with glyphosate between 2008 and 2018 was 152 hectares per year, which was less than 2% of the total area treated with herbicides, and mostly ground-based application was used.

2.2.2 Plantation Survival

Plantations on sites with aggressive competing vegetation complexes can fail within a year without effective vegetation management. In these cases, interventions are often needed to avoid excessive seedling mortality and plantation failure (Comeau et al., 1999; Biring et al., 2003; Comeau and Harper, 2009). This application of glyphosate is particularly important with herbaceous vegetation complexes for which mechanical cutting is not effective, such as bluejoint reed grass. Bluejoint reed grass is a serious competitor in northeastern B.C., where it often colonizes sites after harvest and forms thick colonies that can prevent establishment of shrub and tree species for upwards of 25 years if left uncontrolled (Dunbar et al., 2011). Glyphosate application on these sites can suppress the growth of competitive vegetation, thereby enabling tree seedlings to become established.

2.2.3 Crop Tree Productivity

To meet silvicultural objectives for the site, vegetation management may be required to release established crop trees that are overtopped by competing vegetation and at risk of becoming suppressed. A single application of glyphosate during the first few years after planting in high-brush sites has been shown to effectively improve conifer growth 9–20 years later in a wide range of plant communities in various ecosystems in B.C. (Harper et al., 1997; Whitehead and Harper 1998; Biring et al., 1999; Biring and Hays-Byl 2000; Simard 2001; Harper et al., 2005; Boateng et al., 2006; Macadam and Kabzems 2006). There is substantial variation in the magnitude of reported growth gains because they are dependent on the type, intensity, and duration of vegetation competition; in certain cases, the effects have been found to be significant but can also be short-term (Comeau et al., 1999; Heineman et al., 2005; Comeau and Harper, 2009).

2.2.4 Invasive Species

While the focus of this report is on the use of glyphosate in B.C. silviculture, the herbicide may also be used in forests to control the spread of noxious and invasive weeds across the province. The *Forest Range and Practices Act* (sec 47) indicates that a person who is conducting a forest or range practice must use measures to prevent the introduction or spread of prescribed species of

invasive plants, as listed in the Invasive Plants Regulation. The B.C. *Weed Control Act* requires all land occupiers to control the spread of noxious weeds on their land or premises.

British Columbia has four multi-agency Pest Management Plans (PMPs) for invasive plant management, which together cover the entire province and all invasive plant treatments in B.C. Ministry of Transportation and Infrastructure, FLNRORD, and BC Parks jurisdictions. In 2018, the total area treated with herbicides for control of invasive plant species in these jurisdictions was 1593 ha, 8% of which was treated with glyphosate.[1] However, glyphosate comprised as much as 80% of the total herbicide use in the South Coast PMP program due partly to the focus on Japanese knotweed control. For many noxious weeds, such as knotweeds and some invasive grasses, manual treatments are not effective. Ten-year results from a B.C. study that compared knotweed control methods indicated that manual treatments are ineffective and can actually cause the plants to spread further (C. Chadburn, personal communication, 2019).

Glyphosate products are also used in areas where a short half-life or immobility in the soil is required, where soils, gravels, or other materials may be moved in the future, or near private gardens or other sensitive features. Glyphosate is an important treatment for riparian zones where a significant portion of invasive plants/noxious weeds occur. It is the only herbicide that allows the regulated 10-m pesticide-free zone to be reduced to 1 m when using selective application methods.

2.3 How is Glyphosate Used?

2.3.1 Area Treated

Data from the RESULTS database show that approximately 11,000 ha of Crown land were treated with glyphosate for silvicultural purposes in 2018,[2] with 86% sprayed aerially and 14% sprayed using ground-based methods (Figure 1) (see Appendix 3 for descriptions of aerial, ground-based, and alternative treatment methods). The area sprayed has declined from an average of 13,802 ha from 2013 to 2018 and higher historical levels. The area sprayed in 2018 was 0.044% of the 25 million hectares available for harvesting in B.C. and 0.44% of the tenured area on Crown land that has an outstanding reforestation obligation.

The proportion of area harvested that has had any kind of vegetation control treatment decreased from 18 to 14% between 2008 and 2018. Over that time, herbicides, primarily glyphosate, were applied to half the treated area, while the rest of the area was treated using non-chemical methods (Figure 2), primarily clearing with brush saws (Figure 3). The use of brushing declined due partly to the increase in mountain pine beetle (MPB) salvage. As MPB salvage winds down, BCTS and Interior licensees are moving their harvesting operations to wetter sites with potentially greater brush hazards, which might result in an increase in the need for vegetation control.

---

[1] Compared to 11,000 ha treated with glyphosate in B.C. for silviculture.

[2] Includes aerial and ground-based brushing and site preparation treatments but excludes basal spray and stem bark spray silviculture methods, which do not apply to glyphosate-based herbicides. It may include some triclopyr application that was reported as backpack treatment method. Private land is not included.

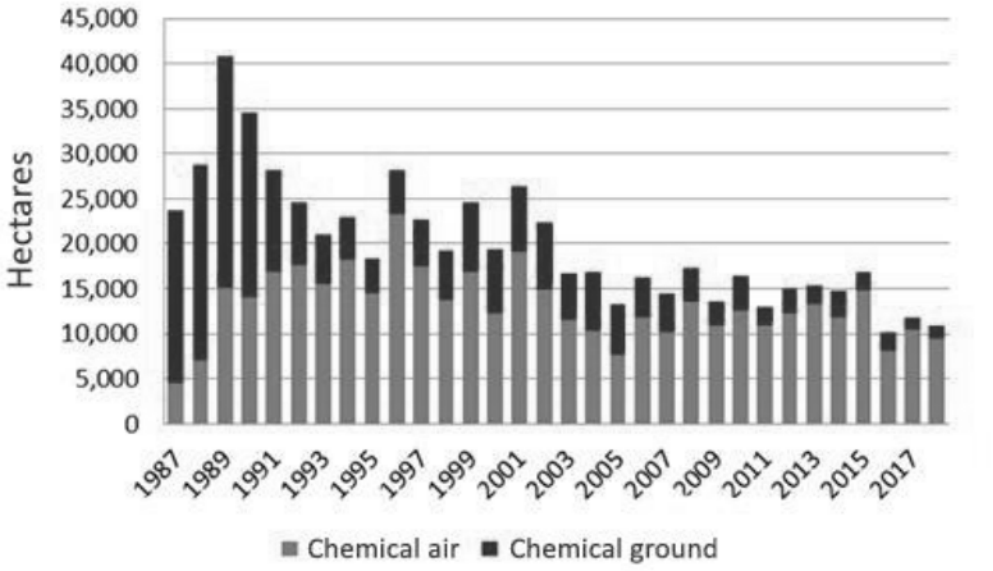


Figure 1. Area sprayed with glyphosate for silviculture in British Columbia.

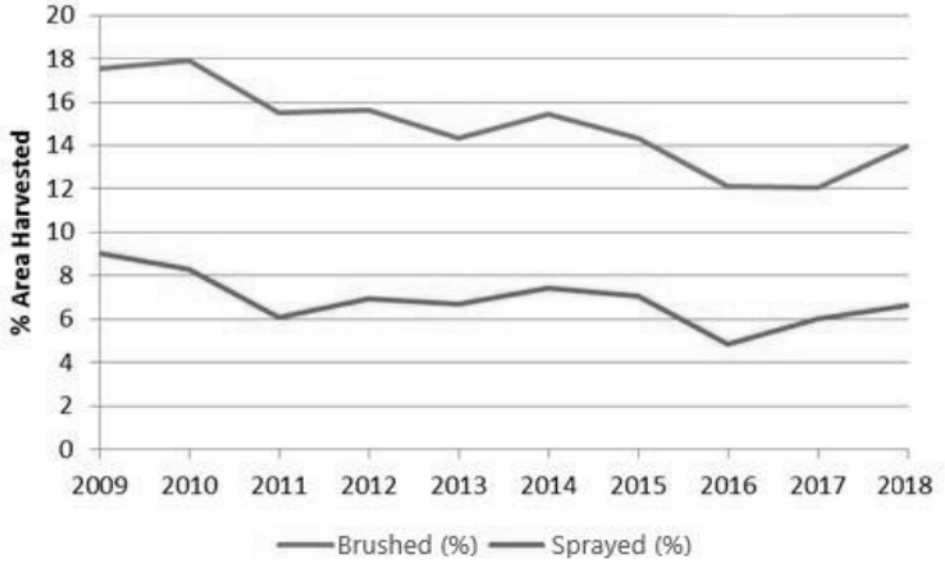


Figure 2. The percentage of harvested area that was brushed using alternative methods and sprayed with glyphosate.

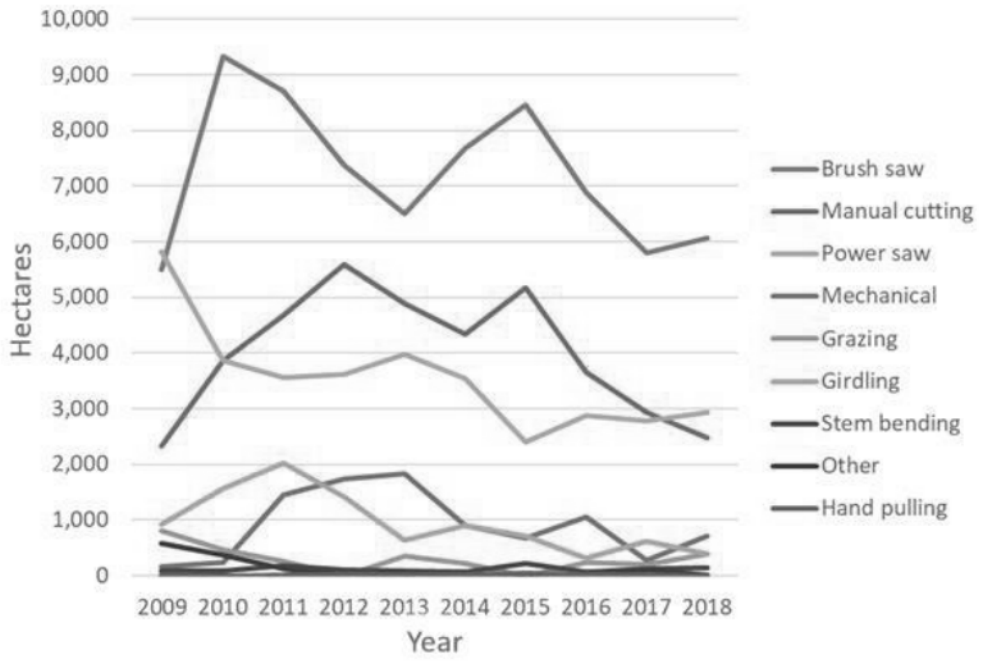


Figure 3. Area brushed using non-chemical methods.

Most of the glyphosate spraying was conducted in the Omineca Natural Resource Region (73% of all area treated), followed by the Northeast Region (11%) (Table 1). The Prince George Timber Supply Area comprised 68% of the total provincial area sprayed with glyphosate in 2018. Aerial applications made up 96% of the spray programs in those regions. Small aerial programs were also conducted in the Thompson-Okanagan and South Coast Regions. Small ground-based programs were conducted in all regions, with the largest occurring in the South Coast Region. The proportions of area harvested that were sprayed with glyphosate ranged from 11 to 15% in the Northeast, South Coast, and Omineca Regions, while less than 3% of the harvested area in the remaining regions was sprayed (Table 1).

Table 1. Area sprayed with glyphosate, by Natural Resource Region, in 2018

Natural Resource Region	Area harvested (ha)	Area treated with herbicide (ha)			% of harvest area
		Aerial	Ground-based	Total	
Omineca	52,795	7,673	301	7,974	15.1
Northeast	11,574	1,179	60	1,239	10.7
Thompson-Okanagan	25,635	565	18	583	2.3
South Coast	4,060	35	520	555	13.7
Kootenay-Boundary	14,333	0	234	234	1.6
West Coast	10,620	0	175	175	1.6
Skeena	16,346	0	169	169	1.0
Cariboo	28,418	0	39	39	0.1
B.C. total	**163,781**	**9,452**	**1,516**	**10,968**	**6.7**

The biogeoclimatic (BEC) zones (Meidinger and Pojar 1991) in which most of the glyphosate application was conducted were the Sub-Boreal Spruce (SBS) (76%) and Boreal White and Black Spruce (BWBS) (9%) zones (Table 2). Four subzones of the SBS accounted for 68% of the total provincial area that was sprayed (Figure 4). The drier SBS subzones (dry warm [dw] and moist cool [mk]) are generally dominated by aspen, while the wetter subzones (wet cool [wk] and very wet cool [vk]) are dominated by herbaceous vegetation.

Table 2. Area sprayed with herbicide, by biogeoclimatic zone, in 2018

BEC zone	Area treated with herbicide (ha)		
	Aerial	Ground-based	Total
Sub-Boreal Spruce (SBS)	7,865	416	8,281
Boreal White and Black Spruce (BWBS)	941	60	1,001
Coastal Western Hemlock (CWH)	27	662	689
Engelmann Spruce – Subalpine Fir (ESSF)	414	135	549
Interior Cedar – Hemlock (ICH)	195	192	387
Interior Douglas-fir (IDF)	0	52	52
Mountain Hemlock (MH)	8	0	8
B.C. total	**9,450**	**1,517**	**10,967**

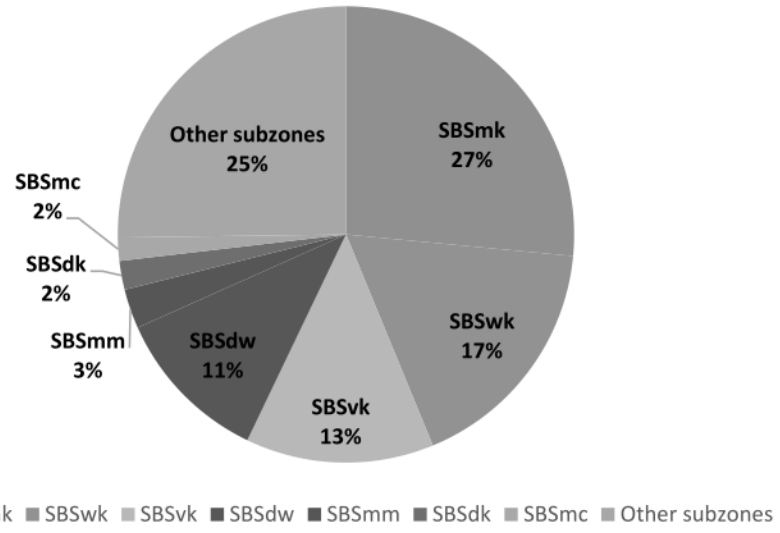


Figure 4. Herbicide use by biogeoclimatic subzone. (SBS: Sub-Boreal Spruce, mk: moist cook, wk: wet cool, vk: very wet cool, dw: dry warm, mm: moist mild, dk: dry cool)

2.3.2 Glyphosate Use at the Stand Level

Glyphosate is generally used in a targeted portion of the total reforestation area, as opposed to covering entire cutovers. In more than two-thirds of all cutovers treated with herbicide since

1998, the treatment area was less than 80% of the total net area to be reforested.[3] The distribution of net area to be reforested that was treated with herbicide is illustrated in Figure 5.

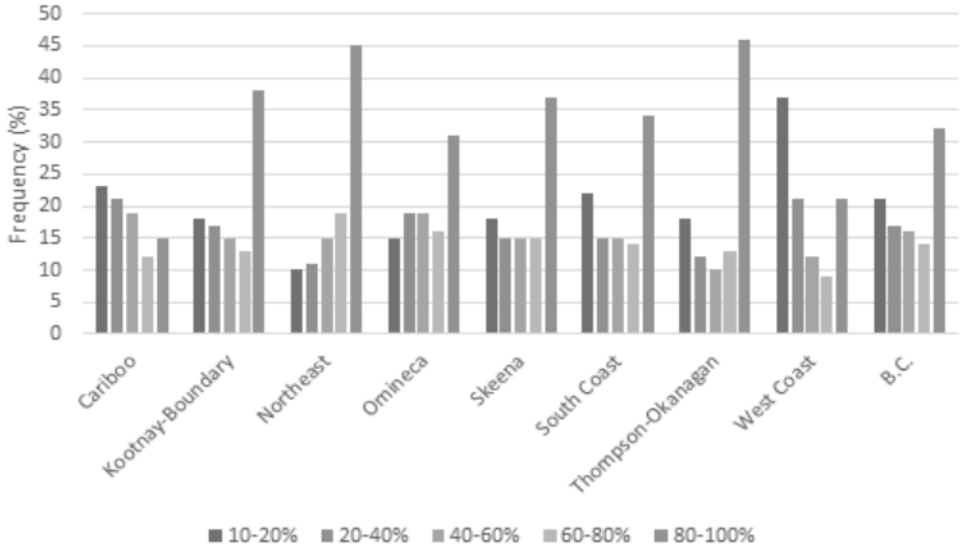


Figure 5. Distribution of the percentage of area treated with glyphosate within the net area to be reforested in a block, since 1998. Data is for one-time treatments only.

In contrast with agriculture and other common land uses where areas are sprayed repeatedly, in forestry, glyphosate is generally applied once or twice in a rotation. Since 1998, 47% of blocks that had ground-based herbicide treatments and 65% that had aerial treatments were treated once (Table 3). The percentage of blocks treated more than twice was 32% for ground-based and 11% for aerial treatments. The Coast regions had a higher proportion of retreatments than other regions. BC Timber Sales and licensees indicated that efforts are made to minimize areas sprayed to reduce costs and address public pressure.

Table 3. Number of herbicide treatments on a given area, since 1998

Natural Resource Region	Ground-based treatment			Aerial treatment		
	Number of treatments			Number of treatments		
	1	2	> 2	1	2	> 2
Cariboo	74%	20%	6%	83%	16%	1%
Kootenay-Boundary	44%	42%	14%	100%	0%	0%
Northeast	64%	25%	12%	53%	30%	17%
Omineca	89%	10%	1%	68%	24%	8%
Skeena	79%	11%	10%	70%	15%	15%
South Coast	41%	29%	30%	79%	21%	0%
Thompson-Okanagan	75%	17%	8%	45%	33%	22%
West Coast	24%	19%	58%	63%	25%	11%
B.C. total	**47%**	**21%**	**32%**	**65%**	**25%**	**11%**

[3] This analysis included blocks that were treated with herbicide only once.

Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species. Commonly targeted vegetation complexes in the SBS, where most of the glyphosate application occurs, are trembling aspen, mixed shrub, fireweed, and wet alder. The BWBS zone is dominated by aspen/poplar and reed grass complexes (Comeau et al., 1996).

Target species are indicated on brushing prescriptions that are developed from operational surveys. A licensee in the Prince George region indicated that 53% of the 2018 aerial spray area targeted aspen, while 47% targeted herbaceous/shrub competition. Aggregated data on which complexes are targeted the most by glyphosate application are currently lacking. More work is required to understand how glyphosate use is distributed among particular vegetation complexes or species to understand how and why glyphosate is used, and what the impact of not using it would be.

2.4 Treatment Costs

Treatment costs vary considerably depending on location, access, treatment intensity, availability of crews and equipment and logistics. BC Timber Sales and licensees reported that manual treatments (Can$700–$1200/ha) are more than twice the cost of glyphosate treatments (Can$300–$500/ha) and require at least two treatments. The cost of achieving free growing on a site that needs vegetation control ranges from Can$900 to Can$2100/ha more when using manual treatments. BC Timber Sales provided an example of treatment costs to attain free growing with and without glyphosate in the Prince George Region (Table 4). Assuming this example is representative and applying an average cost difference of $1400/ha to the 11,000-ha area that was sprayed in 2018, the cost of not using glyphosate for silviculture is estimated at Can$15.4 million per year.

Table 4. Cost of achieving free-growing, Prince George Region (Source: BC Timber Sales)

Activity	Vegetation management with glyphosate	Vegetation management with motor-manual treatments
Plant regular stock ($/ha)	$624	
Plant large stock ($/ha)		$900
Glyphosate application ($/ha)	$354	
Manual brush ($/ha) × 2		$1,460
Surveys	$70	$90
Cost to free-growing	**$1,048**	**$2,450**

Although costs are an important consideration, safety, access, crew availability, treatment windows, and various operational factors also affect the selection of treatment options discussed in Appendix 3.

3 IMPACT OF GLYPHOSATE USE ON NON-TIMBER VALUES

3.1 Biodiversity

The FPPR states that the objective set by the B.C. government for wildlife and biodiversity at the landscape level is, without unduly reducing the timber supply from British Columbia's forests and to the extent practicable, to design areas on which timber harvesting is to be carried out that resemble, both spatially and temporally, the patterns of natural disturbance that occur within the landscape.

3.1.1 Broadleaf Tree Species

Mixedwood forests provide various ecological, social, and non-timber values; have significant value in shaping forest ecology, stand structure, and function; and exert a strong influence on forest diversity and resilience (Harper and Roach 2014). One of the primary concerns the public has expressed regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broad-leaves are being eliminated from the landscape. These claims, however, are not supported by analyses of the amount of deciduous components remaining at free-growing in blocks that have been treated with glyphosate, or the increase in mixed deciduous stands over time as a result of forest management (BC MFLNRO 2008).

3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide treatment

On sites where aspen exists pre-harvest, it regenerates aggressively from suckering after a stand-replacing event such as fire or harvesting (Frey et al., 2003). This is particularly true in the boreal and sub-boreal mixedwoods that comprise large portions of central and northeastern B.C., where research has shown that in order to establish a conifer crop, vegetation management is often required to counter aspen suckering following harvesting[4] (Wood and von Althen, 1993; Cole et al., 2003; Pitt and Bell, 2005; Boateng et al., 2006).

On these sites, deciduous mixes often develop, even after conventional vegetation management treatments (including glyphosate) are used because a percentage of broad-leaves in a treated stratum may survive or produce suckers after treatment (Perala, 1985, Navratil et al., 1991; Bell and Newmaster, 2002; Pitt et al., 2004a, 2004b; Pitt and Bell, 2005; Kabzem and Harper, 2015). Medium- and long-term studies on the effect of a one-time glyphosate application on stand composition in boreal sites have recorded 15–21% deciduous stand components 5–30 years after treatment (Pitt et al., 2004a, 2004b; Pitt and Bell, 2005; Kabzem and Harper, 2015).

While those studies focused on deciduous composition within herbicide-treated areas, it is important to note that glyphosate is not generally applied to entire harvest units (see Section 2.3.2), and that the total elimination of competitive vegetation is not a silvicultural objective of conifer-release programs (Bell and Newmaster, 2002). In B.C., vegetation management

[4] Suckering from a single aspen parent tree can cover 500 m^2 at densities of up to 250,000 sph (Navratil et al. 1991)

treatments, including glyphosate application, are carried out only in the portions of a harvest unit where they are deemed necessary for conifer survival or to meet free-growing stocking standards in each standard unit as per sec 46.11 of the FPPR.

3.1.1.2 RESULTS analyses

A 2008 Forest and Range Evaluation Program review of tree species composition pre- and post-harvest in B.C. found that the amount of deciduous mixed stands at free growing increased from 2811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods (BC MFLNRO 2008). Similarly, in the Southern Interior Forest Region, deciduous mixed stands increased from 1202 ha before harvest to 37,268 ha at free growing, a 3000% increase.

An up-to-date RESULTS query of stand composition for all stands declared free growing following herbicide treatment (aerial and ground-based) was prepared by FLNRORD. The inventory labels from free-growing surveys were examined for openings that were sprayed > 5 years after harvest and surveyed 2–25 years after spraying. The data showed that province-wide, the average number of deciduous stems per hectare (sph) in a survey polygon after aerial and ground-based treatment was 504 and 449, respectively (Table 5). This corresponds to 16% and 15% broadleaf components (by stem density).

In the Omineca and Northeast Regions, where most herbicide treatments are conducted, the average number of deciduous stems per hectare at free growing after aerial herbicide treatments was 445 and 864, respectively, or 15% and 27% of the total stand species composition (Table 5). Similarly, in the SBS zone (the BEC zone where most herbicide application occurs), there was an average of 455 and 577 sph of deciduous at free growing for aerially and ground-based treated openings, respectively. The averages in Table 5 do not show the variation in sample sizes and stocking that can occur from year to year or among openings.

In general, for most regions, ground-based application resulted in a slightly higher number and percentage of deciduous stems at free growing compared with aerial application. Backpack-type application can be more selective compared to broadcast aerial treatments, and leave untreated stems between crop trees, which is less likely with aerial broadcast treatment.

Table 5. Deciduous stocking at free growing following aerial or ground-based herbicide treatments

Natural Resource Region	Deciduous components, post-aerial treatments		Deciduous components, post-ground-based treatments	
	Average deciduous density (sph)[a]	Deciduous component (%)	Average deciduous density (sph)	Deciduous component (%)
Omineca	445	14.7	699	21.2
Northeast	864	26.5	828	27.6
Cariboo	436	9.6	583	12.6
South Coast	94	4.8	120	7.2
Kootenay-Boundary	130	4.1	185	5.2
Skeena	237	8.9	230	7.7
Thompson-Okanagan	–	–	355	8.9
West Coast	–	–	449	14.6

B.C. Average	**504**	**16.4**	**449**	**14.6**

– Missing values indicate no survey data for the region.

[a] sph: stems per hectare

The results of the analysis suggest that deciduous stocking does recover after glyphosate spraying and may in fact be increasing over time with forest management activities. Deciduous components are important for many forest management objectives (e.g., wildlife habitat, wildfire, carbon), yet they also affect timber supply objectives. Research shows that increases in deciduous volume in a stand negatively affect conifer volume (Kabzems et al., 2007; Harper and Roach, 2014; Harper, 2015) (see Section 3.3).

3.1.2 Non-Target Plant Communities

3.1.2.1 Diversity of plant communities

A review of 12 studies found that species richness and diversity of non-target vascular plants was not negatively affected when measured 5–12 years after glyphosate application (Sullivan and Sullivan 2003). Studies report that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as 1–2 years after treatment (Freedman et al., 1993; Bell and Newmaster, 1998; Sullivan et al., 1998; Lautenschlager and Sullivan, 2002; Hawkins et al., 2013; Comeau and Fraser, 2018). In many cases, herbaceous vegetation abundance, diversity, and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank (Sullivan and Sullivan, 2003; Kabzems and Harper, 2015).

While broadcast aerial spraying of glyphosate is sometimes seen as a blunt vegetation management tool, studies have found that it does not target all vegetation equally. One study found that on sites with a vertical vegetation structure (comprised of aspen, shrubs, and forbs), most of the spray was deposited in the aspen canopy (68% of the nominal application rate), while shrubs and herbs captured approximately 25% and 12% of the nominal application rate, respectively, which may further help explain their quick recovery (Thompson et al., 1997).

Only two of the 12 studies Sullivan and Sullivan (2003) analyzed showed an overall reduction in species richness of shrubs after glyphosate application (Sullivan et al., 1998; Santillo et al., 1989). Santillo et al. (1989) found that species richness decreased by 50% and 30% for shrubs and herbs, respectively, 1 year after treatment and continued to be lower in the treatment units after 3 years. However, the control sites in this study were at a different successional stage than the glyphosate treatment units (Santillo et al., 1989). Sullivan et al. (1988) likewise observed a reduction in shrub species richness 5 years after treatment.

Other brushing alternatives such as manual brushing may have effects similar to glyphosate application on plant community composition. Lindgren and Sullivan (2001) compared manual cutting of stump sprouts and cut-stump application of glyphosate, and found no difference in species richness, diversity, structural diversity, or turnover of herbaceous, shrub, and tree communities. In a similar study, Bell and Newmaster (2002) showed that herbicides had a relatively greater initial effect on plant community composition compared to two mechanical vegetation control treatments, but that woody, herb, and grass layers recovered to pre-treatment levels within 5 years.

3.1.2.1 Persistence of glyphosate/aminomethylphosphonic acid in plant tissue

Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions (Gomes et al., 2014) due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least 1 year (Wood 2019). Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality; however, some translocation into shoots and fruit was observed in select plants (Wood 2019). While residue levels were non-toxic to humans and wildlife, little is known about the persistence timelines of residues, their effect on forage quality, and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

3.1.3 Aquatic Organisms

Amphibian populations are declining around the world (Houlahan et al., 2000), and chemical contaminants released into aquatic environments have been listed as the second most important threat to amphibians after habitat loss (Edge et al., 2011). Laboratory and mesocosm studies have shown direct effects of chronic exposures to glyphosate-based herbicides, particularly those containing the polyethoxylated tallow amine surfactant, on fish, amphibians, invertebrates, and other components of aquatic ecosystems (e.g., Folmar et al., 1979; Wan et al., 1989; Edglnton et al., 2004; Howe et al., 2004; Edge et al., 2014a, Lanctot et al., 2014, Navarro-Martin et al., 2014). However, studies have not been able to replicate these toxicity effects in the field under typical application rates and conditions.

Numerous whole-ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development (Edge et al., 2012, 2014b; Lanctot et al., 2013), expression of genes related to larval development (Lanctot et al., 2013), or juvenile amphibian survival (Edge et al., 2011, 2013). This is likely due to the short (but environmentally realistic and relevant) exposure duration (generally less than 96 hours) and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands (Edge et al., 2012, 2014b; Baker et al., 2016).

A watershed-level study in coastal B.C. found temporary stress effects and minor mortality (2.6%) in caged coho salmon smolt in an experimentally over-sprayed tributary and the main stream below the sprayed area immediately after glyphosate application. No acute mortality or changes in overwinter mortality, growth rate, or use of the tributary were observed for resident coho (Feng et al., 1990; Legris and Couture, 1991; Reynolds et al., 1993). Similarly, no effects on growth, behaviour, or histopathology of gills and livers of resident rainbow trout were found after a two-month exposure to herbicide in a separate tank experiment (Morgan and Kiceniuk, 1992).

Studies have found temporary effects on aquatic ecosystems due to changes in the vegetation after direct glyphosate application to water bodies. One study showed that glyphosate application caused a decrease in total macrophyte cover and species richness, an increase in species evenness, and a reduction in community similarity when compared to unexposed wetland sites (Baker et al., 2016). One year after herbicide applications, the wetland vegetation began to recover. Studies on aquatic macroinvertebrates have found similar results: one study found that 10% of the benthic macroinvertebrate taxa were eliminated after herbicide application but recovered in 1 year (Baker et al., 2014). Similarly, Linz (1999) reported no

negative effects and even increased arthropod abundance 1 year after direct overspray of a wetland. Rzymski et al. (2013) found no difference in taxa diversity but slight decreases in abundance of some taxa, which where hypothesized to be short term.

While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations require the maintenance of pesticide-free zones around water features, dry streams, and classified wetlands (IPMR, sec. 73 (1)), which further reduces the risk of negative effects on aquatic ecosystems. Various Canadian studies on surface water glyphosate residue have found no detectable glyphosate or AMPA concentrations (i.e., < 5000 ug a.i./L) post-treatment when using buffers of 100 m for aerial and 10–60m for ground applications (Eremko, 1986; Wan, 1986; Gluns, 1989; Adams et al., 2007). Canadian Water Quality Guidelines for the protection of aquatic wildlife stipulate maximum short-term and long-term glyphosate exposures of 27,000 ug a.i./L and 800 ug a.i./L, respectively[5] (CCME, 2012).

3.1.4 Wildlife

3.1.4.1 Toxicity

Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals, and birds have found risk quotients below the level of concern when typical field application rates were used (Giesy et al., 2000; Durkin et al., 2003; PMRA, 2015). Some uncertainty remains regarding the effects of long-term chronic exposure to low levels of glyphosate on wildlife due to glyphosate persistence in forage. While recorded residue levels were non-toxic to mammals, the effects of chronic sub-lethal exposure to mammals are not yet well-understood and require more research (Mesnage et al., 2015; Kissane and Sheppard, 2017; Wood, 2019).

Effects on terrestrial wildlife communities, like in aquatic ecosystems, are linked primarily to the changes in vegetation cover and forage quality. As such, species responses are highly variable and reflect individual habitat preferences. Studies on wildlife responses to habitat alteration due to glyphosate application have shown no effect, short-term negative effects, and positive effects on different wildlife species (Guynn et al., 2004). All in all, studies suggest that species richness and diversity of small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes are transient and related to changes in vegetation structure (Sullivan and Sullivan 2003).

3.1.4.1 Forage quality and quantity

Moose populations have been declining in several regions of B.C., and forage availability and quality has been flagged as a potential contributing cause (Kuzyk et al., 2018). Glyphosate treatment has been found to reduce wildlife forage availability in the short term (as compared to no vegetation control treatment), which results in reduced moose use of glyphosate-treated areas for the first few years after treatment (Hjeljord and Gronvold 1988; Connor and McMillan 1990; Lautesnschlager, 1993; Eschholz et al., 1996; Lautenschlager et al., 1999). The long-term impact of glyphosate use on habitat selection by moose is not well understood, however. Biring

[5] Values are based on median lethal dose (LC_{50}) data for 19 aquatic species.

et al. (1999) reported reduced forage abundance and use 12 years after glyphosate application in a BWBS site. However, Newton reported a 46% decrease in forage abundance the year following glyphosate application but a 660% increase at year 8 compared to the control (Newton et al., 1989), and some studies have shown that 7–11 years post-treatment, moose seem to favour treated areas over controls (Eschholz et al., 1996; Raymond et al., 1996). These impacts must also be considered in relation to the area that is treated annually and its distribution over the landscape (Lautenschlager and Sullivan 2002).

The effects of glyphosate's chelating properties on forage quality and nutrient availability are poorly understood. The properties allow glyphosate to bind macronutrients and micronutrients (in particular iron, manganese, zinc, copper, and nickel), which can impact uptake and availability in plants treated with glyphosate (Mertens et al., 2018). These micronutrients are particularly important to ungulates such as moose, whose sensitivities to mineral imbalances (in particular copper) have been implicated in moose population declines in Alaska, Sweden, and Minnesota (Flynn et al., 1977; Frank et al., 1994; O'Hara et al., 2001; Custer et al., 2004).

Studies on nutrient uptake by surviving plants in agricultural settings after glyphosate application have provided contradictory accounts (Gomes et al., 2014). In some cases, a reduced uptake of micronutrients by plants has been found (Eker et al., 2006; Cakmak et al., 2009; Tesfamariam et al., 2009), while in others (Duke et al., 2012, 2018), no effect on micronutrient content was found. More research on whether glyphosate application leads to reduced micronutrient content specifically in wildlife forage is required, and whether this is implicated in the moose population declines in B.C.

3.2 Soil and Water Quality

3.2.1 Glyphosate/aminomethylphosphonic acid fate in soils

After application, glyphosate is largely immobilized in the soil due to its strong sorption characteristics, which allow it to bind with soil particles and organic materials. Once glyphosate reaches the soil, the main pathway for its dissipation in soil is microbial degradation, as many species of soil microorganisms can use glyphosate as their soil carbon source (Durkin, 2003). One of the main compounds released during the microbial breakdown process, AMPA, is likewise adsorbed to soils and biodegraded, yet it is considered to be a mild phytotoxin (Reddy et al., 2004; Gomes et al., 2014) with relatively unknown long-term effects on soil organisms and plants.

Sorption and degradation processes are highly dependent on microbial activity and soil composition (Székács and Darvas, 2012). The rate of sorption and degradation of both glyphosate and AMPA vary greatly in agricultural applications, with half-lives ranging from a few days to several months, and even up to 1 year (Székács and Darvas, 2012). While it has been argued that the short growing season in northern climates may restrict degradation, North American studies in forest applications have found that the time for 50% dissipation (DT_{50}) in litter and soil is 8–19 days and 5–40 days, respectively (Newton et al., 1984, 1994; Feng and Thompson, 1990; Thompson et al., 2000; Hagner et al., 2019).

3.2.2 Soil microorganisms

Soil organisms play a crucial role in nutrient cycling and maintaining ecosystem productivity. Research on the effect of glyphosate on microorganisms in laboratory studies has been contradictory. Those studies have found exposure to glyphosate formulations may either reduce (Estok et al., 1989; Sanogo et al., 2000; Diaz et al., 2003; Tanney and Hutchinson, 2010; Druille et al., 2013; Zaller et al., 2014) or rarely stimulate (Laatikainen and Heinonen-Tanski 2002; Diaz et al., 2003) proliferation of certain fungal species. Laboratory studies on cultured microorganisms are likely to overestimate toxicity effects (Estok et al., 1989), however. Field studies on the effect of glyphosate application on forest soil organisms and microbial processes are limited, and their findings are often contradictory. Some detrimental effects on fungal communities and nutrient cycling have been documented (Vitousek et al. 1992; Munson et al. 1993). Similarly, annual applications of glyphosate in an Ontario plantation over a 5-year period have resulted in reduced microbial biomass and carbon, and a reduced soil organic carbon ratio, which indicates a reduced capacity of the ecosystem to maintain its nutrient reservoir (Ohtonen et al., 1992). In contrast, other field studies have found minimal or no effect on microbial processes or fungal community structures (Chakravarty and Chatarpaul, 1990; Stratton and Steward, 1992; Busse et al., 2001; Haney et al., 2002; Houston et al., 2002), while others have found a short-term increase in microbial activity caused by the breakdown of glyphosate and AMPA (Wardle and Parkinson 1990; Haney et al., 2002; Ratcliff et al., 2006; Mijangos et al., 2009). The extent of the variation in results suggests that more research on forest applications of glyphosate is needed to better understand direct effects on microbial communities. Research should examine effects on individual species and indirect impacts resulting from these changes in the ecosystem.

3.2.3 Glyphosate/aminomethylphosphonic acid fate in water

The mandated use of pesticide-free zones around water features, the strong sorption of glyphosate to upper soil layers, and the rapid uptake of glyphosate by plants minimize the risk of the herbicide entering aquatic ecosystems. The main ways that glyphosate could enter aquatic ecosystems are by drift onto non-target areas or by soil particle mobilization after a storm event in the hours following glyphosate application (Rolando et al. 2017). These risks may be minimized in field operations by using electronic guidance systems, low drift nozzles, and meteorological monitoring of wind speed, air temperature, and humidity (Thompson et al., 2012). Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are implemented (Gluns, 1989; Feng and Thompson 1990; Thompson et al., 2004; Adams et al., 2007).

Most North American field studies in streams and wetlands have shown that if glyphosate moves into water sources, its DT50 is less than 5 days, and there are no detectable residues after 15 days (Newton et al., 1984, 1994; Gluns, 1989; Goldsborough and Beck, 1989; Wan et al., 1989; Feng and Thompson, 1990; Thompson et al., 2004; Adams et al., 2007). One study in boreal ponds found a half-life of up to 11 days (Goldsborough and Brown, 1993).

The primary mechanisms involved in the rapid breakdown or reduction of glyphosate in the water column are adsorption into benthic or suspended sediments, microbial breakdown of glyphosate and its breakdown products, and downstream dilution. Glyphosate persists longer in oligotrophic water bodies or those that are cold and deep and have low microbial activity. Residues have been detected in benthic sediments of these systems up to 18 months after glyphosate application (Newton et al., 1984, 1994; Feng et al., 1990).

3.3 Climate Change

The Intergovernmental Panel on Climate Change notes that "in the long-term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit" (Nabuurs et al., 2007). Vegetation management (including, but not limited to, glyphosate application) can affect carbon sequestration due to its impact on vegetation structure and stand productivity. When used to control herbaceous or shrub vegetation, for example, it allows the establishment of a woody crop, which delivers immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools.

When competing species are aspen or other deciduous species, however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with the site and species. Mixedwood stands comprised of spruce and aspen are likely to have a higher yield than either pure spruce or pure aspen stands because of differences in shade tolerance, phenology, rooting patterns, and physical space occupied by different sized canopies (McCulloch and Kabzems 2009; Gough et al., 2019). Retaining between 1000 and 10,000 sph of aspen is expected to increase total stand production by approximately 20% relative to a pure spruce stand, but this will be at the expense of spruce volume (Kabzems et al., 2007). Harper and Roach (2014) similarly report that in a modelled mixedwood, the total stand volume was higher in a spruce–aspen mixedwood than in pure spruce or pure aspen stands.

Growth and yield models for the SBS show that total stand volumes in lodegepole pine–aspen stands are not different from those in pure aspen or pure pine stands (Harper, 2015). In all cases, the increase in deciduous volume is at the expense of conifer volume (Kabzems et al., 2007; Harper and Roach, 2014; Harper, 2015; Harper, 2017).

Forest soils are the largest carbon pool in boreal and temperate ecosystems, often storing greater amounts of carbon than living biomass and coarse woody debris (Heath et al., 2003). Laganiere et al. (2017) found that aspen trees stored less carbon in the forest floor and similar amounts in the mineral soil relative to conifers. However, their study also showed that soil organic carbon stock under aspen was more stable, which rendered it more protected against environmental changes and soil disturbances.

A source of uncertainty in determining the difference in carbon sequestration between mixedwoods and pure conifer stands is the shorter lifespan of deciduous trees compared to conifers, which ultimately affects the amount of time that a stand can act as a carbon sink (Harper and Roach, 2014).

3.4 Wildfire

Vegetation management (including, but not limited to, glyphosate application) has the potential to alter the number of deciduous trees left on a site after regeneration. Deciduous stands often act as natural fire breaks. In summer, deciduous stands moderate microclimates, inhibit wind movement, help maintain lower air temperature and higher humidity, and maintain soil and surface fuel moisture longer into the fire season when compared to conifer-dominated stands (Chesterman, 1997). The Canadian Forest Fire Behaviour Prediction System predicts that it takes more extreme moisture conditions for high-intensity fires to build in deciduous fuel types than in coniferous fuel types (Taylor et al., 1996).

The physical properties of aspen, in particular, resist intense fire behaviour, which makes it a popular choice for fuel treatments in the wildland–urban interface throughout North America (Shepperd et al., 2006; Gray 2018). Generally, fire does not get carried into the crowns of deciduous stands due to the absence of ladder fuels. Consequently, fires in deciduous stands are usually slower moving surface fires, which are easier to suppress than crown fires (Alexander and Lanoville, 2004). The Forest Fire Behaviour Prediction System indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous[6] or leaf-on mixedwood stands. Among deciduous trees, poplars show the most fire resistance (Table 6).

The effect of fire behaviour associated with deciduous vegetation that is treated with glyphosate is not well documented. It is expected that the fire hazard in dead stems following either manual or chemical treatment would be high because dead aspen burns very hot (R.W. Gray, personal communication, 2019).

Table 6. Fire resistance of broad-leaved species (BC MFLNRORD 2019)

Fire resistance/resilience	Broad-leaved species
High	Balsam poplar, black cottonwood
High–Moderate	Gary oak, bigleaf maple
Moderate	Trembling aspen, red alder, paper birch
Low	Arbutus

3.5 First Nations

Some First Nations in B.C. have expressed concern over the use of glyphosate in forests. Some of these concerns relate to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated. Chief Ron Ignace (Skeetchestn Indian Band) has indicated that he considers the spraying of herbicide “an act of cultural genocide, because you are killing our foods and medicines.”[7] The McLeod Lake Indian Band passed a Band Council resolution in July 2019 that reaffirms the Band’s zero tolerance for herbicide, pesticide, insecticide, and chemical fertilizer use within the traditional territory. The resolution indicates that glyphosate is deemed carcinogenic and has a direct impact on wildlife, ecosystems, and water sources. Where there is doubt concerning the science about herbicides, there can be an inclination toward the precautionary principle.

Two-way education, communication, collaboration, and joint problem-solving between stakeholders is key to reaching agreements about land use. Traditional plant users should, for example, take into consideration that the presence of glyphosate does not indicate toxicity (Wood, 2019) or that plant diversity, richness, and abundance is not generally affected in the years following application. Similarly, forest managers need to acknowledge and communicate uncertainty regarding minor effects of glyphosate use. There is mounting evidence, for example, that glyphosate/AMPA may persist in low levels in some perennial plants (Wood, 2019), and

[6] During spring, before leaf-out in deciduous stands, the grass has the potential to dry out rapidly in the absence of canopy cover, which creates a higher surface fire potential until green-up and leaf-on occurs.
[7] https://acuriouslookatpoliticsinbc.blogspot.com/2019/09/adam-olsen-skeetchestn-indian-band.html?fbclid=IwAR3kXSjKGMzGu6V5qs4Gxvu9l06PdbVbL5TtjdfWvallemumCz0TiAsRnaQ

that it may also disrupt the creation of some plant secondary compounds, some of which may be the compounds responsible for medicinal effects in traditional medicines (Gomes et al., 2014).

Relationship building between licensees and First Nations takes time and effort, but proactive and informed engagement can often solve problems. Discussion at the land use planning stage can help build mutual understanding, and ensuring that stakeholders understand silvicultural concepts of vegetation competition and the need for brushing to re-establish some stands after harvest will lead to more productive discussions.

Engagement with First Nations can also be conducted through the referral process within a PMP, which calls for meaningful consultation and accommodation. Licensees have indicated that within this framework, efforts can be, and often are, made to accommodate the specific concerns of First Nations by:

- designating no-spray areas;
- prioritizing manual treatments;
- prioritizing backpack instead of aerial application;
- prioritizing spot spray around individual stems;
- increasing buffers;
- leaving untreated patches;
- providing alternative plant gathering sites;
- providing additional notification and signage; and
- adjusting treatment schedules to avoid disrupting First Nations activities.

3.6 Public Use

Forest managers are faced with mounting public pressure over the safety of glyphosate use (Thomson and Pitt, 2011). Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts on human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping, or hiking. The Canada Pest Management Regulatory Agency's review on glyphosate (PMRA, 2017) addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health. This applies to people who may come in contact with glyphosate through food or water, by handling the product, or by entering treated sites.

Currently, there is no evidence that suggests that glyphosate application can cause game meat contamination because glyphosate has not been shown to accumulate in animal tissues (including in game species such as moose, deer, and hare) (Newton et al., 1984; Legris and Couture, 1991; Lautenschlager, 1992). Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, localized primarily in roots but sometimes found in shoot and fruit tissue (Wood, 2019). Where detected, glyphosate residue levels averaged 0.79 ppm (the highest level detected was 4 ppm) 1 year after

application. From a food consumption perspective, 0.1 ppm is the maximum residue level allowed for non-designated food in Canada, although this value ranges from 0.08 to 40.00 for specific foods. While the persistence timeline in forest plants is not well understood, persistence is expected to be more transient than in agricultural settings because in forestry, glyphosate is typically used only once or twice over an entire rotation.

Better communication between forest managers and recreational users about the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, can help address key public concerns and build trust. On-site signage after glyphosate treatment, which is currently required in B.C. under IPMR sec 63.1 and outlines safety precautions, could be used to address some of the current knowledge gaps (Wood, 2019).

4 IMPACTS ON TIMBER SUPPLY

Vegetation control, including but not limited to glyphosate application, is necessary in some cases to supress competing vegetation and allow crop trees to become established and grow unimpeded. The unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests. Vegetation management is one key tool for meeting these objectives.

Glyphosate is used in this context because of its cost-effectiveness compared to manual vegetation control methods. Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in not satisfactorily restocked area, particularly problematic areas, with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

In Canada, decisions to not use chemical herbicides have been made in Quebec and Nova Scotia. In Quebec, a provincial ban of glyphosate use on Crown land took effect in 2001 after severe public pressure and a series of public consultations. Forest regeneration focuses on early planting of tall stock and intensive manual brushing. Since then, plantation establishment and tending costs have frequently exceeded $5000/ha due to planting large stock and to the need to apply as many as three manual brushing treatments (Labbé et al., 2014). Dampier et al. (2006) reported that cost per cubic metre of wood tripled when conifer release was performed by motor-manual methods rather than aerial application of herbicide.

In addition to the increases in reforestation costs, there were challenges in managing plantations where the objective was to maximize wood production (Thiffault and Roy, 2011). Manual brushing alone was not effective in controlling competing vegetation and did not promote optimal crop tree growth due to rapid resprouting or suckering of competitors and competition from herbaceous species. Since the glyphosate ban, the Quebec Chief Forester's Office has reported challenges in reaching proper stocking throughout the province. In some areas, more than half the plantations have failed to meet required stocking due to severe competition (Bureau du forestier en chef, 2015).

An audit of plantations in Nova Scotia after a decision was made to not use herbicides yielded similar findings. Following a survey of untreated plantations, 87% of conifer plantations were

considered failures (with less than 60% stocking), and only 3% met free-growing standards 6–8 years post-harvest (Nicholson, 2007).

In B.C., meeting free-growing stocking standards ensures that sustainable timber supply is achieved. In cases where aggressive competing vegetation cannot be overcome to the extent that is practicable to meet free-growing requirements, licensees may request relief from reforestation obligations under FPPR sec 97.1. Increasing the challenge to meet reforestation obligations on a broad scale may increase the risk of reduced plantation performance with significant timber supply impacts, such as in Quebec.

4.1 Managing for Multiple Values

Forest management decisions related to achieving landscape objectives are reflected in stocking standards. Where stocking standards require the re-establishment of coniferous forests after harvest, with the objective of maintaining healthy forests and long-term fibre supply, studies show that competing vegetation control is necessary in some cases and that glyphosate is a highly effective vegetation control tool that has minimal and transient impacts on the ecosystem.

Where non-timber objectives such as increasing broadleaf stand components for wildfire risk reduction or wildlife are identified as priorities, current free-growing stocking standards may be overly restrictive (Harper and Roach, 2014). License holders have indicated that more flexibility and better guidance and support for alternative stocking standards could facilitate reduced brushing (including but not limited to glyphosate use) and accommodate other non-timber values. An example of one such mechanism is the Fort St. John pilot project, which allows for 2 ha, or 20%, of not satisfactorily restocked area over the landscape. The concept allows for areas of poor performance to be compensated by areas of superior performance, which in turn allows greater flexibility and efficiency of resources in areas where higher yields can be achieved, and avoids expensive, poor-value treatments, while accommodating non-timber values.

Landscape-level plans that link objectives to operational plans with a rationale for stocking standards could provide priorities for competing objectives on the land base.[8] For example, stocking standards in areas where managing for wildfire breaks or wildlife habitat are identified as priorities need to reflect a higher acceptance of broadleaf species over conifers, with the understanding that timber supply may be negatively affected. There are ongoing efforts to further develop standards that facilitate deciduous management in the context of overall forest management objectives. One example is the inclusion of fire stocking standards in the wildland–urban interface, including the establishment and management of deciduous species to reduce fire behaviour in areas near communities and infrastructure. In another example, a Hardwood Management Strategy was developed in 2008 to facilitate management of red alder, bigleaf maple, and birch in the Coast Region. Wildlife stocking standards are also being developed, and regional guidance is available.

[8] Challenges in addressing multiple forest management objectives such as timber supply, biodiversity, resilience, etc. at the operational level are identified in the Forest Practices Board's (2019) Special Report, *Tactical Forest Planning: The Missing Link Between Strategic and Operational Planning in BC.*

Alternative stocking standards for a Forest Stewardship Plan must be supported with science and justified with timber supply considerations and other tests as per FPPR 26(5). In some parts of the province, the focus on coniferous species remains a hurdle to applying alternative standards because the science for deciduous management is not well understood at the operational level. Licensees have indicated that further supporting research and guidance, such as that found in Newsome and Heineman's (2016) mixedwood stocking standards for the Cariboo Region, would assist them in developing stocking standards that can better incorporate other non-conifer values.

5 RECOMMENDATIONS

s.13

6 CONCLUSIONS

Glyphosate is one of many vegetation management tools available to forest managers. It is used to help maintain plantation survival and to meet free-growing obligations that ensure stand productivity and sustainable timber supply. Forest managers are faced with mounting public pressure over the perceived environmental impacts of forestry applications of glyphosate—in particular, concerns over the removal of broadleaf tree species from the landscape and the consequent impacts on risk of wildfire, wildlife habitat, resiliency, climate change, etc. A review of current inventory data, however, shows that stands that have been treated with glyphosate retain 15–21% deciduous components at free growing, and that the area comprised of deciduous–mixed stands has been increasing over time as a result of forest management activities in general.

Field studies have also shown that the effects of glyphosate and its metabolites on the environment are minimal when the herbicide is applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals, songbirds, and invertebrates remain within the range of natural variation, and that changes to communities tend be transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects of glyphosate on soil microorganisms, its chelating effects on soil and plant nutrients, and its persistence in plants that survive treatment. More research is still needed to understand some of the impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.

While more research on the identified knowledge gaps is recommended, the use of glyphosate needs to be viewed from a landscape perspective, considering the amount of area treated, the short time scale of stand-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape levels. Put into perspective, vegetation management is just one component of the many silvicultural decisions that affect forest management in B.C. Many of the challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by building better linkages between site- and landscape-level planning that allows other non-timber values to be prioritized where needed.

7 REFERENCES

Adams, G. W., Smith, T., & Miller, J. D. (2007). The absence of glyphosate residues in wet soil and the adjacent watercourse after a forestry application in New Brunswick. *Northern Journal of Applied Forestry, 24*(3), 230–232.

Alexander, M. E., & Lanoville, R. A. (2004). The International Crown Fire Modelling Experiment fuel treatment trials [Abstract]. In R .T. Engstrom, K.E.M. Galley, & W.J. de Groot (Eds.). *Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems* (222). Tallahassee, FL : Tall Timbers Research Station.

Baker, L. F., Mudge, J. F., Houlahan, J. E., Thompson, D. G., & Kidd, K. A. (2014). The direct and indirect effects of a glyphosate-based herbicide and nutrients on Chironomidae (Diptera) emerging from small wetlands. *Environmental Toxicology and Chemistry, 33*, 2076–2085.

Baker, L. F., Mudge, J. F, Thompson, D. G, Houlahan, J. E, & Kidd, K. E. (2016). The combined influence of two agricultural contaminants on natural communities of phytoplankton and zooplankton. *Ecotoxicology , 25*, 1021–1032.

Bell, F. W., & Newmaster, S. G. (2002). The effects of silvicultural disturbances on the diversity of seed-producing plants in the boreal mixedwood forest. *Canadian Journal of Forest Research, 32*(7), 1180–1191. Retrieved from https://digitalcommons.usu.edu/aspen_bib/389

Bell, F.W., and Newmaster, S.G. (1998). Falling snow ecosystem project: floral richness, abundance and diversity. In Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability—Popular Summaries, 1998, Sault Ste.-Marie, Ont. Compiled by R.G. Wagner and D.G. Thompson. Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, Ont. For. Res. Inf. Pap. 141. pp. 45–47

Biring, B. S., Comeau, P. G., & Fielder, P. (2003). Long-term effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia. *Annals of Forest Science, 60*(7), 681-690.14.
Biring, B. S., & Hays-Byl, W. J. (2000). *Ten-year conifer and vegetation responses to glyphosate treatment in the SBSdw3*. (Extension Note 46). Victoria, BC: B.C. Ministry of Forests.

Biring, B. S., Hays-Byl, W. J., & Hoyles, S. E. (1999). *Twelve-year conifer and vegetation responses to discing and glyphosate treatments on a BWBSmw backlog site* (Working Paper 43). Victoria, BC: B.C. Ministry of Forests.

Boateng, J. O., Heineman, J. L., McClarnon, J., & Bedford, L. (2006).Twenty year responses of white spruce to mechanical site preparation and early chemical release in the boreal region of northeastern British Columbia. *Canadian Journal of Forest Research, 36*, 2386–2399.

British Columbia Ministry of Forests, Lands and Natural Resource Operations (BC MFLNRO). (2008). *Tree species composition and diversity in British Columbia* (FREP Report #14). Victoria, BC.

British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development (BC MFLNRORD). (2018). *Silviculture surveys procedures manual: regen delay, stocking and free growing surveys plus alternative survey methodologies*. Victoria, BC. Retrieved from https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

Bureau du forestier en chef. (2015). Succes des plantations. Avis du Forestier en chef. FEC-AVIS-04-2015, Roberval, Québec.

Busse, M. D., Ratcliff, A. W., Stestak, C.J., & Powers, R. F. (2001). Glyphosate toxicity and the effects of long-term vegetation control on soil microbial communities. *Soil Biology & Biochemistry, 33*, 1777–1789.

Canadian Council of Ministers of the Environment (CCME). (2012). Canadian water quality guidelines for the protection of aquatic life: glyphosate. In *Canadian environmental quality guidelines*. Winnipeg , MB.

Cakmak, I., Yazici, A., Tutus, Y., & Ozturk, L. (2009). Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium, and iron in non-glyphosate resistant soybean. *European Journal of Agronomy, 31*(3), 114–119.

Chakravarty, P. , & Chatarpaul, L. (1990). Non-target effect of herbicides: II. The influence of glyphosate on ectomycorrhizal symbiosis of red pine (*Pinus resinosa*) under greenhouse and field conditions. *Pesticide* S*cience*, *28*(3), 243–247.

Chesterman, D. A. 1997. *Microclimate of aspen forests*. (Unpublished master's thesis). University of Alberta, Edmonton, AB.

Cole, E., Youngblood, A., & Newton, M. (2003). Effects of competing vegetation on juvenile white spruce (*Picea glauca*(Moench)Voss) growth in Alaska. *Annals of Forest Science, 60*, 1–11.

Comeau, P.G., Braumandl, T.F. and Xie, C.Y. (1993). Effects of overtopping vegetation on light availability and growth of Engelmann spruce (Picea engelmannii) seedlings. *Canadian Journal of Forest Research*, 23(10), pp.2044-2048.

Comeau, P. G., Biring, B. S., & Harper, G. J. (1999). *Conifer response to brushing treatments: a summary of British Columbia data* (Extension Note 41). Victoria, BC: B.C. Ministry of Forests.

Comeau, P. G., Biring, B. S., & Harper, G. J. (2000). Effectiveness of repeated manual cutting and glyphosate for release of Engelmann spruce from mixed-shrub herb vegetation. *Western Journal of Applied Forestry, 15*(3), 154–162. http://dx.doi.org/10.1093/wjaf/15.3.154

Comeau, P., & Fraser, E. (2018). Plant community diversity and tree growth following single and repeated glyphosate herbicide applications to a white spruce plantation. *Forests, 9*(3), 107.

Comeau, P. G., & Harper, G. J. (2009). Effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia Year 15 results. *Forestry Chronicle, 85*(4), 583–592.

Comeau, P. G., Harper, G., Blache, M. E., Boateng, J. O., & Gilkeson, L. (1996). Integrated forest vegetation management: options and applications. In P. G. Comeau, G. J. Harper, M. E. Blache, J. O. Boateng, & L. A. Gilkeson (Eds.). *Proceedings of the Fifth B.C. Forest Vegetation Management Workshop* (FRDA Report 51). Victoria, BC: B.C Ministry of Forests & B.C, Ministry of Environment, Lands and Parks.

Connor, J. F., & McMillan, L. M. (1990). *Winter utilization by moose of glyphosate-treated cutovers*. Toronto, ON: Ontario Ministry of Natural Resources.

Custer, T. W., Cox, E., & Gray, B. (2004). Trace elements in moose (*Alces alces*) found dead in northwestern Minnesota, USA. *Science of the Total Environment, 330*(1), 81–87.

Dampier, E. E., Bell, F. W., St-Amour, M., Pitt, D. G., & Luckai, N. J. (2006). Cutting versus herbicides: tenth-year volume and release cost-effectiveness of sub-boreal conifer plantations. *Forestry Chronicle, 82*(4), 521–528. Retrieved from https://pubs.cif-ifc.org/doi/10.5558/tfc82521-4

Diaz, G., Carrillo, C., & Honrubia, M. (2003). Differential responses of ectomycorrhizal fungi to pesticides in pure culture. *Cryptogamie Mycologie, 24*, 199–211.

Druille, M., Cabello, M. N., Omacini, M., & Golluscio, R. A. (2013). Glyphosate reduces spore viability and root colonization of arbuscular mycorrhizal fungi. *Applied Soil Ecology, 64*, 99–103.

Duke, S. O., Lydon, J., Koskinen, W. C., Moorman, T. B., Chaney, R. L., & Hammerschmidt, R. (2012). Glyphosate effects on plant mineral nutrition, crop rhizosphere microbiota, and plant disease in glyphosate-resistant crops. *Journal of Agricultural and Food Chemistry, 60*(42), 10375–10397.

Duke, S. O., Rimando, A. M., Reddy, K. N., Cizdziel, J. V., Bellaloui, N., Shaw, D. R., Williams, M. M., & Maul, J. E. (2018). Lack of transgene and glyphosate effects on yield, and mineral and amino acid content of glyphosate-resistant soybean. *Pest Management Science, 74*(5), 1166–1173.

Dunbar, J., McCulloch, L., & Kabzems, R. (2011). Bluejoint stand establishment decision aid. *Journal of Ecosystems and Management, 11*(3).

Durkin, P. R. (2003). *Glyphosate - human health and ecological risk assessment report*. Fayetteville, NY: Syracuse Environmental Research Associates Inc.

Edge, C. B., Gahl, M. K., Pauli, B. D, Thompson, D. G., & Houlahan, J.E. (2011). Exposure of juvenile green frogs (*Lithobates clamitans*) in littoral enclosures to a glyphosate-based herbicide. *Ecotoxicology and Environmental Safety, 74*, 1363–1369.

Edge, C., Gahl, M., Thompson, D., Hao, C., & Houlahan, J. (2014a). Variation in amphibian response to two formulations of glyphosate-based herbicides. *Environmental Toxicology and Chemistry, 33,* 2628–2632.

Edge, C. B., Gahl, M. K., Thompson, D. G., & Houlahan, J. E. (2013). Laboratory and field exposure of two species of juvenile amphibians to a glyphosate-based herbicide and *Batrachochytrium dendrobatidis*. *Science of the Total Environment, 444*, 145–152.

Edge, C. B., Thompson, D. G., Hao, C., & Houlahan, J. E. (2012). A silviculture application of the glyphosate-based herbicide VisionMAX to wetlands has limited direct effects on amphibian larvae. *Environmental Toxicology and Chemistry, 31*, 2375–2383.

Edge, C., Thompson, D., Hao, C., & Houlahan, J. (2014b). The response of amphibian larvae to exposure to a glyphosate-based herbicide (Roundup WeatherMax) and nutrient enrichment in an ecosystem experiment. *Ecotoxicology and Environmental Safety, 109*, 124–132.

Edginton, A. N., Sheridan, P. M., Stephenson, G. R., Thompson, D. G., & Boermans, H. J. (2004). Comparative effects of pH and Vision® herbicide on two life stages of four anuran amphibian species. *Environmental Toxicology and Chemistry: An International Journal*, *23*(4), 815–822.

Ehrentraut, G., & Brantner, K. (1990). Vegetation management by manual and mechanical means in Alberta boreal forests. *Forestry Chronicle, 66*, 366–368.

Eker, S., Ozturk, L., Yazici, A., Erenoglu, B., Romheld, V., & Cakmak, I. (2006). Foliar-applied glyphosate substantially reduced uptake and transport of iron and manganese in sunflower (*Helianthus annuus* L.) plants. *Journal of Agricultural and Food Chemistry, 54*(26), 10019–10025.

Eremko, R.D. (1986). *The effects of the aerial application of Roundup on water quality in the Nicoamen River watershed*. Unpublished report. B.C. Ministry of Forests and Lands, Lillooet District.

Eschholz, W. E., Servello, F. A., Griffith, B., Raymond, K. S., & Krohn, W. B. (1996). Winter use of glyphosate-treated clearcuts by moose in Maine. *Journal of Wildlife Management, 60*, 764–769.

Estok, D., Freedman, B., & Boyle, D. (1989). Effects of the herbicides 2,4-D, glyphosate, hexazinone, and triclopyr on the growth of three species of ectomycorrhizal fungi. *Bulletin of Environmental Contamination and Toxicolology, 42*(6), 835–839. doi:10.1007/BF01701623

Feng, J. C., & Thompson, D. G. (1990). Fate of glyphosate in a Canadian forest watershed. 2. Persistence in foliage and soils. *Journal of Agricultural and Food Chemistry, 38*(4), 1118–1125.

Feng, J. C., Thompson, D. G., & Reynolds, P.E. (1990). Fate of glyphosate in a Canadian forest watershed. 1. Aquatic residues and off-target deposit assessment. *Journal of Agricultural and Food Chemistry, 38*(4), 1110–1118.

Flynn, A., Franzmann, A. W., Arneson, P. D., & Oldemeyer, J. L. (1977). Indications of copper deficiency in a subpopulation of Alaskan moose. *Journal of Nutrition, 107*(7), 1182–1189.

Folmar, L. C., Sanders, H. O., & Julin, A. M. (1979). Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. *Archives of Environmental Contamination and Toxicology, 8*(3), 269–278. https://doi.org/10.1007/BF01056243

Frank, A., Galgan, V., & Petersson, L. R. (1994). Secondary copper deficiency, chromium deficiency and trace element imbalance in the moose (*Alces alces* L.): effect of anthropogenic activity. *Ambio, 23*(4–5), 315–317.

Freedman, B., Morash, R., & MacKinnon, D. (1993). Short-term changes in vegetation after the silvicultural spraying of glyphosate herbicide onto regenerating clearcuts in Nova Scotia, Canada. *Canadian Journal of Forest Research, 23*(10), 2300–2311.

Frey, B. R., Lieffers, V. J., Landhäusser, S. M., Comeau, P. G., & Greenway, K. J. (2003). An analysis of sucker regeneration of trembling aspen. *Canadian Journal of Forest Research, 33*(7), 1169–1179.

Giesy, J. P., Dobson, S., & Solomon, K. R. (2000). Ecotoxicological risk assessment for Roundup® herbicide. In G.W. Ware (Ed.). *Reviews of environmental contamination and toxicology*. (Vol 167, 35–120). New York, NY: Springer.

Gluns, D. R. (1989). *Herbicide residue in surface water following an application of Roundup® in the Revelstoke Forest District* (RR 88001-NE). B.C. Ministry of Forests and Lands.

Goldsborough, L. G., & Beck, A. E. (1989). Rapid dissipation of glyphosate in small forest ponds. *Archives of Environmental Contamination and Toxicology*, *18*(4), 537–544.

Goldsborough, L. G., & Brown, D. J. (1993). Dissipation of glyphosate and aminomethylphosphonic acid in water and sediments of boreal forest ponds. *Environmental Toxicology and Chemistry 12*(7), 1139–1147.

Gomes, M. P., Smedbol, E., Chalifour, A., Hénault-Ethier, L., Labrecque, M., Lepage, L., Lucotte, M., & Juneau, P. (2014). Alteration of plant physiology by glyphosate and its by-product aminomethylphosphonic acid: an overview. *Journal of Experimental Botany*, *65*(17), 4691–4703.

Gough, C. M, Atkins, J. W., Fahey, R. T., & Hardaman, B.S. (2019). High rates of primary production in structurally complex forests. *Ecology, 100*(10). https://doi.org/10.1002/ecy.2864

Gray, R. W. (2018). *Trembling aspen stands as firebreaks: what options are available for stimulating aspen stand expansion*. Cranbrook, BC: UBCM Fuel Management Pilot Program. Retrieved from https://wfca.ca/wp-content/uploads/2018/06/Trembling-Aspen-Stands-as-Firebreaks_FINAL-REPORT.pdf

Guynn, D. C., Guynn, S. T., Wigley, T. B., & Miller, D. A. (2004). Herbicides and forest biodiversity: What do we know and where do we go from here? *Wildlife Society Bulletin, 32*(4), 1085–1092.

Hagner, M., Mikola, J., Saloniemi, I., Saikkonen, K., & Helander, M. (2019). Finnish ecological sustainability study: glyphosate-based Roundup herbicide has 'minor, transient' impacts on soil and animal health. *Scientific Reports 9*(1), 8540. doi.org/10.1038/s41598-019-44988-5

Haney, R. L., Senseman, S. A., & Hons, F. M. (2002). Effect of Roundup Ultra on microbial activity and biomass from selected soils. *Journal of Environmental Quality*, *31*(3), 730–735.

Harper, G. J. (2015). Lodgepole pine and trembling aspen mixedwoods: growth and yield within 22 to 39 year old pine plantations of northern interior British Columbia. *Forestry Chronicle, 91*(5), 502–518.

Harper, G. (2017). Lodgepole pine and trembling aspen competition: neighbourhood studies within 22 to 39 year old pine plantations of northern British Columbia. *Forestry Chronicle, 93*{3), 226–240. https:// doi .org/10.5558/tfc2017-031

Harper, G. J., Biring, B. C., & Heineman, J. (1997). *Mackay River herbicide trial: conifer response 9 years post-treatment* (Research Report 11). B.C. Ministry of Forest.

Harper, G. J., Comeau, P. G., & Biring, B. S. (2005). A comparison of herbicide and mulch mat treatments for reducing grass, herb, and shrub competition in the B.C. Interior Douglas-fir zone—ten-year results. *Western Journal of Applied Forestry, 20*(3), 167–176.

Harper, G., & Roach, J. (2014). *The role of broadleaf trees: impacts of managing boreal and sub-boreal mixedwood forests in British Columbia* (Extension Note 110). Victoria, BC: B.C. Ministry of Forests and Range.

Hart, D., & Comeau, P.G. (1992). *Manual brushing for forest vegetation management in British Columbia: a review of current knowledge and information needs* (Land Management Report 77). Victoria, BC: B.C. Ministry of Forests.

Hawkins, C. D. B., Dhar, A., & Lange, J. (2013). Vegetation management with glyphosate has little impact on understory species diversity or tree growth in a sub boreal spruce plantation—a case study. *Plant Biosystems, 147*(1), 105–114.

Heath, L. S., Kimble, J. M., Birdsey, R. A., & Lal, R. (2003). The potential of U.S. forest soils to sequester carbon. In J. M. Kimble, L. S. Heath, R. A. Birdsey, & R. Lal (Eds.). *The potential of U.S. forest soils to sequester carbon and mitigate the greenhouse effect* (385–394). Boca Raton: CRC Press.

Heineman, J. L., Simard, S. W., Sachs, D. L., & Mather, W. J. (2005). Chemical, grazing, and manual cutting treatments in mixed herb-shrub communities have no effect on interior spruce survival or growth in southern interior British Columbia. *Forest Ecology and Management, 205*(1–3), 359–374. https:// doi .org/10.1016/j. foreco.2004.10.038

Hjeljord, O., & Grønvold, S. (1988). Glyphosate application in forest—ecological aspects: VI. Browsing by moose (*Alces alces*) in relation to chemical and mechanical brush control. *Scandinavian Journal of Forest Research*, *3*(1–4), 115–121.

Houlahan, J. E., Findlay, C. S., Schmidt, B. R., Meyer, A. H., & Kuzmin, S. L. (2000). Quantitative evidence for global amphibian population declines. *Nature, 404*, 752–755.

Houston, A. P. C., Visser, S., & Lautenschlager, R. A. (2002). Response of microbial processes and fungal community structure to vegetation management in mixedwood forest soils. *Canadian Journal of Botany, 76*(12), 2002–2010.

Howe, C. M., Berrill, C. M., Pauli, B. D., Helbing, C. C., Werry, K., & Veldhoen, N. (2004). Toxicity of glyphosate-based pesticides to four North American frog species. *Environmental Toxicology and Chemistry, 23*, 1928–1938.

Kabzems R., & Harper, G. J. (2015). *Conifer and vegetation responses to pre-planting applications of glyphosate and hexazinone on a boreal backlog site, Sx trial 82502g-2* (Technical Report 087). Victoria, BC: Province of British Columbia. Retrieved from www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr087.htm

Kabzems, R., Nemec, A. L., & Farnden, C. (2007). Growing trembling aspen and white spruce intimate mixtures: early results (13–17 years) and future projections. *BC Journal of Ecosystems and Management, 8*(1), 1–14. Retrieved from http://www.forrex.org/publications/jem/ISS39/vol8 no1 artl.pdf

Kissane, Z., & Shephard, J. M. (2017). The rise of glyphosate and new opportunities for biosentinel early-warning studies. *Conservation Biology, 31*(6), 1293–1300.

Kuzyk, G., Marshall, S., Procter, C., Schindler, H., Schwantje, H., Gillingham, M., Hodder, D., White, S., & Mumma, M. (2018). *Determining factors affecting moose population change in British Columbia: testing the landscape change hypothesis. 2018 progress report: February 2012–April 2018* (Wildlife Working Report No. WR-126). Victoria, BC: B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Laatikainen, T., & Heinonen-Tanski, H. (2002). Mycorrhizal growth in pure cultures in the presence of pesticides. *Microbiological Research 157*(2), 127–137. doi: 10.1078/0944-5013-00139

Labbé, F., Lainesse, M., Nadeau, F-R., Prégent, G., & Savary, A. (2014). Analyse de rentabilité économique des plantations d'épinette noire et blanche et de pin gris. Bureau de mise en marché des bois, Québec (Québec). Retrieved from https://www.bmmb.gouv.qc.ca/analyses-economiques/

Laganiere, J., Boca, A., Van Miegroet, H., & Pare, D. (2017). A tree species effect on soil that is consistent across the species' range: the case of aspen and soil carbon in North America. *Forests, 8*, 113.

Lanctot, C., Navarro-Martin, L., Robertson, C., Park, B., Jackman, P., Pauli, B. D., & Trudeau, V. L. (2014). Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frog (*Lithobates sylvaticus*) tadpoles. II: Agriculturally relevant exposures to Roundup WeatherMax® and Vision® under laboratory conditions. *Aquatic Toxicology, 154*, 291–303.

Lanctot, C., Robertson, C., Navarro-Martin, L., Edge, C., Melvin, S. D., Houlahan, J., & Trudeau, V. L. (2013). Effects of the glyphosate-based herbicide Roundup WeatherMax® on metamorphosis of wood frogs (*Lithobates sylvaticus*) in natural wetlands. *Aquatic Toxicology, 140–141*, 48–57.

Lautenschlager, R. A. (1992). Effects of conifer release with herbicides on moose: browse production, habitat use, and residues in meat. *Alces, 28*, 215–222.

Lautenschager, R. A. (1993). Response of wildlife to forest herbicide applications in northern coniferous ecosystems. *Canadian Journal of Forest Research 23*, 2286–2299.

Lautenschlager, R. A., Dalton, W. J., Cherry, M. L., & Graham, J. L. (1999). Conifer release alternatives increase aspen forage quality in northwestern Ontario. *Journal of Wildlife Management, 63,* 1320–1326.

Lautenschlager, R. A., & Sullivan, T. P. (2002). Effects of herbicide treatments on biotic components in regenerating northern forests. *Forestry Chronicle,* 78, 1–37.

Legris, J., & Couture, G. (1991). Residus de Glyphosate dans le Gibier (Lievre, Orignal Qt cerf de Virginie) Suite a des Pulverisations en Milieu Forestier en 1988; Quebec Ministere des Forest, Direction de I' evaluation Environnementale: Charlesbourg, QC.

Lindgren, P. M. F., & Sullivan, T. P. (2001).Influence of alternative vegetation management treatments on conifer plantation attributes: abundance, species diversity, and structural diversity. *Forest Ecology and Management, 142*(1–3), 163–182.

Linz GM, Bleier WJ, Overland JD, Homan HJ. (1999). Response of invertebrates to glyphosate-induced habitat alterations in wetlands. *Wetlands,* 19, 220–227.

Macadam, A., & Kabzems, R. (2006). Vegetation management improves early growth of white spruce more than mechanical site preparation treatments. *Northern Journal of Applied Forestry*, 23(1), 35–46. https://doi.org/10.1093/njaf/23.1.35

McCulloch, L., & Kabzems, R. (2009). British Columbia's northeastern forests: aspen complex stand establishment decision aid. *BC Journal of Ecosystems and Management, 10*(2), 51–58. Retrieved from https://jem-online.org/index.php/jem/article/view/419

Meidinger, D. V., & Pojar, J. (1991). *Ecosystems of British Columbia* (Special Report Series 6). Victoria, BC: B.C. Ministry of Forests.

Mertens, M., Höss, S., Neumann, G., Afzal, J., & Reichenbecher, W. (2018). Glyphosate, a chelating agent—relevant for ecological risk assessment. *Environmental Science and Pollution Research, 25*(6), 5298–5317.

Mesnage, R., Defarge, N., De Vendômois, J.S., & Seralini, G.E. (2015). Potential toxic effects of glyphosate and its commercial formulations below regulatory limits. *Food and Chemical Toxicology, 84*, 133–153.

Mijangos, I., Becerril, J. M., Albizu, I., Epelde, L., & Garbisu, C. (2009). Effects of glyphosate on rhizosphere soil microbial communities under two different plant compositions by cultivation-dependent and-independent methodologies. *Soil Biology and Biochemistry*, *41*(3), 505–513.

Miller, D. T. (1985). Conifer release in the inland northwest – effects. In *Weed control for forest productivity in the interior west*. *Symposium Proceedings* (17–24). Spokane, WA: Washington State University.

Morgan, M. J., & Kiceniuk, J. W. (1992). Response of rainbow trout to a two month exposure to Vision®, a glyphosate herbicide. *Bulletin of Environmental Contamination and Toxicology, 48*, 772–780.

Munson, A. D., Margolis, H. A., & Brand, D. G. (1993). Intensive silvicultural treatment: impacts on soil fertility and planted conifer response. *Soil Science Society of America Journal*, *57*(1), 246–255.

Nabuurs, J., Masera, O., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., Elsiddig, E., FordRobertson, J., Frumhoff, P., Karjalainen, T., Krankina, O., Kurz, W., Matsumoto, M., Oyhantcabal, W., Ravindranath, N., Sanz, M. Sanchez, T., & Zhang, X. (2007). Forestry. In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds). *Climate change 2007: mitigation*. Contribution of Working Group Ill to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Navarro-Martin, L., Lanctot, C., Jackman, P., Park, B. J., Doe, K., Pauli, B. D., & Trudeau, V. L. (2014). Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frogs (*Litho bates sylvaticus*) tadpoles. 1: Chronic laboratory exposures to Vision Max®. *Aquatic Toxicology, 154*, 278–290.

Navratil, S., Branter, K., & Zasada, J. (1991). Regeneration in the mixedwoods. In A. Shortreid (Ed.). *Proceedings of the Symposium on Northern Mixedwoods '89* (32–48). (FRDA Report 164). Victoria, BC: Forestry Canada, Pacific Forestry Centre.

Newsome, T. A., & Heineman, J. L. (2016). Adjusting free-growing guidance regarding aspen retention in the Cariboo-Chilcotin: research to operational implementation (Technical Report 102). Victoria, B.C: Province of British Columbia. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/TR102.htm

Newton, M., Cole, E. C., Lautenschlager, R. A., White, D. E., & McCormack, M. L., Jr. (1989). Browse availability after conifer release in Maine's spruce-fir forests. *Journal of Wildlife Management, 53*, 643–649.

Newton, M., Horner, L. M., Cowell, J. E., White, D. E., & Cole, E. C. (1994). Dissipation of glyphosate and aminomethylphosphonic acid in North American forests. *Journal of Agricultural and Food Chemistry, 42*(8), 1795–1802.

Newton, M., Howard, K. M., Kelpsas, B. R., Danhaus, R., Lottman, C. M., & Dubelman, S. (1984). Fate of glyphosate in an Oregon forest. *Journal of Agricultural and Food Chemistry, 32*,1144–1151.

Nicholson, J. (2007). *Survey of plantations established between 1998–2000 (6–8 years of age) on eastern Crown land without herbicides* (Forest Research Report 83). Nova Scotia Department of Natural Resources.

O'Hara, T. M., Carroll, G., Barboza, P., Mueller, K., Blake, J., Woshner, V., & Willetto, C. (2001). Mineral and heavy metal status as related to a mortality event and poor recruitment in a moose population in Alaska. *Journal of Wildlife Diseases, 37*(3), 509–522.

Ohtonen, R., Munson, A., & Brand, D. (1992). Soil microbial community response to silvicultural intervention in coniferous plantation ecosystems. *Ecological Applications*, *2*(4), 363–375.

Perala, D. A. (1985). *Using glyphosate herbicide in converting aspen to conifers* (Research Paper NC-259). St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.

Pesticide Management Regulatory Agency (PMRA). (2015). *Glyphosate revaluation decision RVD2015-1*. Health Canada.

Pesticide Management Regulatory Agency (PMRA). (2017). *Glyphosate revaluation decision RVD2017-1*. Health Canada.

Pesticide Management Regulatory Agency (PMRA). (2019). Statement from Health Canada on glyphosate. Health Canada. Retrieved from https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

Pitt, D. G., & Bell, F. W. (2005). Juvenile response to conifer release alternatives on aspen–white spruce boreal mixedwood sites. Part I: Stand structure and composition. *Forestry Chronicle, 81*(4), 538–547.

Pitt, D. G., Mihajlovich, M., & Proudfoot, L. M. (2004b). Juvenile stand responses and potential outcomes of conifer release efforts on Alberta's spruce aspen mixedwood sites. *Forestry Chronicle, 80*(5), 583–597.

Pitt, D. G., Wagner, R. G., & Towill, W. D. (2004a).Ten years of vegetation succession following ground-applied release treatments in young black spruce plantations. *Northern Journal of Applied Forestry 21*(3), 123–134.

Ratcliff, A. W., Busse, M. D., & Shestak, C.J. (2006). Changes in microbial community structure following herbicide (glyphosate) additions to forest soils. *Applied Soil Ecology*, *34*(2–3), 114–124.

Raymond, K. S., Servello, F. A., Griffith, B., & Eschholz, W. E. (1996). Winter foraging ecology of moose onglyphosate-treated clearcuts in Maine. *Journal of Wildlife Management, 60*, 753–763.

Reddy, K. N., Rimando, A. M., & Duke, S. O. (2004). Aminomethylphosphonic acid, a metabolite of glyphosate, causes injury in glyphosate-treated, glyphosate-resistant soybean. *Journal of Agricultural and Food Chemistry*, 52, 5139–5143.

Reynolds, P . E., Scrivener, J. C., Holtby, L. B., & Kingsbury, P. D. (1993). Review and synthesis of Carnation Creek herbicide research. *Forestry Chronicle, 69*(3), 323–330.

Rolando, C. A., Baillie, B. R., Thompson, D. G., & Little, K. M . (2017). The risks associated with glyphosate-based herbicide use in planted forests. *Forests, 8*(6), 208–233. Retrieved from https://www.mdpi.com/1999-4907/8/6/208

Rzymski, P., Klimaszyk, P., Kubacki, T., & Poniedziałek, B. (2013). The effect of glyphosate-based herbicide on aquatic organisms – a case study. *Limnological Review, 13*(4), 215–220.

Sanogo, S., Yang , X. B., & Scherm, H. (2000). Effects of herbicides on Fusarium solanif. sp. glycines and development of sudden death syndrome in glyphosate-tolerant soybean. *Phytopathology, 90*(1), 57–66. doi: 10.1094/PHYTO.2000.90.1.57

Santillo, D. J., Leslie, D. M., Jr., & Brown, P. W. (1989). Responses of small mammals and habitat to glyphosate application on clearcuts. *Journal of Wildlife Management, 53*, 164–172.

Shepperd, W. D., Rogers, P. C., Burton, D., & Bartos, D. L. (2006). *Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada* (General Technical Report RMRS-GTR-178). Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Simard, S. (2001). *Effects of operational brushing on conifers and plant communities in the Southern Interior of British Columbia: results from PROBE 1991–2000, PRotocol for Operational Brushing* (Land Management Handbook 48). Victoria, BC: B.C. Ministry of Forests. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh48.pdf

Stratton, G.W. and Stewart, K.E., (1992). Glyphosate effects on microbial biomass in a coniferous forest soil. Environmental toxicology and water quality, 7(3), 223-236.

Sullivan, T.P., Wagner, R.G., Pitt, D.G., Lautenschlager, R.A., and Chen, D.G. (1998). Changes in diversity ofplant and small mammal communities after herbicide application in sub-boreal spruce forest. Canadian Journal of Forest Research, 28, 168–177.

Sullivan, T. P., & Sullivan, D. S. (2003). Vegetation management and ecosystem disturbance impact of glyphosate herbicide on plant and animal diversity in terrestrial ecosystems. *Environmental Review, 11*, 37–59.

Székács, A., & Darvas, B. (2012). Forty years with glyphosate. In M. N. A. E.-G. Hasaneen (Ed.). *Herbicides – properties, synthesis and control of weeds*. InTech: Rijeka, Croatia.

Tanney, J. B., & Hutchison, L. J. (2010). The effects of glyphosate on the in vitro linear growth of selected microfungi from a boreal forest soil. *Canadian Journal of Microbiology, 56*(2), 138–144.

Tarazona, J. V., Court-Marques, D., Tiramani, M., Reich, H., Pfeil, R., lstace, F., & Crivellente, F. (2017). Glyphosate toxicity and carcinogenicity: a review of the scientific basis of the European Union assessment and its differences with IARC. *Archives of Toxicology, 91*(8), 2723–2743.

Taylor, S. W., Pike, R. G., & Alexander, M. E. (1996). *Field guide to the Canadian forest fire behaviour prediction (FPB) system* (FRDA Handbook 012). Victoria, BC: Canadian Forest Service and B.C. Ministry of Forests. Retrieved from https://www.for.gov.bc.ca/hfd/pubs/Docs/Frh/Frh012.pdf

Tesfamariam, T., Bott, S., Cakmak, I., Römheld, V., & Neumann, G. (2009). Glyphosate in the rhizosphere—role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants. *European Journal of Agronomy, 31*(3), 126–132.

Thiffault, N., & Roy, V. (2011). Living without herbicides in Québec (Canada): historical context, current strategy, research and challenges in forest vegetation management. *European Journal of Forest Research, 130*, 117–133. Retrieved from https://rd.springer.com/article/10.1007/s10342-010-0373-

Thompson, D., Leach, J., Noel, M., Odsen, S., & Mihajlovich, M. (2012). Aerial forest herbicide application: comparative assessment of risk mitigation strategies in Canada. *Forestry Chronicle, 88*(2), 176–184.

Thompson, D. G., & Pitt, D. G. (2011). *Frequently asked questions (FAQs) on the use of herbicides in Canadian forestry* (Frontline Technical Note 112). Canadian Forest Service, Great Lakes Forestry Centre.

Thompson, D. G., Pitt, D. G., Buscarini, T. M., Staznik, B., & Thomas, D. R. (2000). Comparative fate of glyphosate and triclopyr herbicides in the forest floor and mineral soil of an Acadian forest regeneration site. *Canadian Journal of Forest Research, 30*, 1808–1816.

Thompson, D. G., Pitt, D. G., Staznik, B., Payne, N. J., Jaipersaid, D., Lautenschlager, R. A., et al. (1997). On-target deposit and vertical distribution of aerially released herbicides. *Forestry Chronicle, 73*(1), 47–59.

Thompson, D. G, Wojtaszek, B. F., Staznik, B., Chartband, D. T., & Stephenson, R. (2004). Chemical and biomonitoring to assess potential acute effects of VisonR herbicide on native amphibian larvae in forest wetlands. *Environmental Toxicology and Chemistry, 23*, 843–849.

Vitousek, Peter & Andariese, Steven & Matson, Pamela & Morris, Lawrence & Sanford Jr, Robert. (1992). Effects of harvest intensity, site preparation, and herbicide use on soil nitrogen transformations in a young loblolly pine plantation. *Forest Ecology and Management*. 49. 277-292.

Wan, M. T. K. (1986). The persistence of glyphosate and its metabolite amino- methyl-phosphonic acid in somecoastal British Columbia streams. Regional Program Report 85-01. Dep. Environ., Environ. Prot. Serv., Vancouver, B.C

Wan, M. T., Watts, R. G. & Moul, D. J. (1989). Effects of different dilution water types on the acute toxicity to juvenile pacific salmonids and rainbow trout of glyphosate and its formulated products. *Bulletin of Environmental Contamination and Toxicology, 43*, 378–385. https://doi.org/10.1007/BF01701872

Wardle, D. A., & Parkinson, D. (1990). Influence of the herbicide glyphosate on soil microbial community structure. *Plant and Soil, 122*(1), 29–37.

Whitehead, R. J., & Harper, G. J. (1998). *A comparison of four treatments for weeding Engelmann spruce plantations in the Interior Cedar Hemlock Zone of British Columbia: ten years after treatment* (Information Report BC-X-379). Victoria, BC: Canadian Forest Service, Pacific Forestry Centre.

Wood, J. L. (2019). The presence of glyphosate in forest plants with different life strategies one year after application. *Canadian Journal of Forest Research, 49*(6), 586–594. https://doi.org/10.1139/cjfr-2018-0331

Wood, J. E., & von Althen, F. W. (1993). Establishment of white spruce and black spruce in boreal Ontario: effects of chemical site preparation and post-planting weed control. *Forestry Chronicle 69*, 554–560.

Zaller, J. G., Heigl, F., Ruess, L., & Grabmaier, A. (2014). Glyphosate herbicide affects belowground interactions between earthworms and symbiotic mycorrhizal fungi in a model ecosystem. *Scientific Reports, 4*, 5634.

APPENDIX 1. INTERNATIONAL ASSESSMENTS

Various international expert panels and regulators have reviewed glyphosate and its effect on human health. The consensus among national pesticide regulatory agencies and scientific organizations is that labelled uses of glyphosate have demonstrated no evidence of human carcinogenicity (Tarazona et al., 2017).

International Agency for Research on Cancer

In March 2015, the World Health Organization's International Agency for Research on Cancer (IARC), consisting of 17 experts from 11 countries, classified glyphosate as "probably carcinogenic in humans" based on epidemiological studies, animal studies, and in vitro studies.[9] This was based on "limited" evidence of cancer in humans (from exposures that actually occurred) and "sufficient" evidence of cancer in experimental animals (from studies of "pure" glyphosate). "Limited" evidence means that a positive association between exposure to the agent and cancer has been observed but that other explanations for the observations (called chance, bias, or confounding) could not be ruled out.

The International Agency for Research on Cancer also concluded that there was "strong" evidence for genotoxicity, both for "pure" glyphosate and for glyphosate formulations.[10]

European Food Safety Authority

In October 2015, the European Food Safety Authority of the European Union (EU) concluded that "the substance is unlikely to be genotoxic (i.e., damaging to DNA) or to pose a carcinogenic threat to humans."[11]

Glyphosate was not proposed to be classified as carcinogenic under the EU regulation for classification, labelling, and packaging of chemical substances. In particular, all the member state experts but one agreed that neither the epidemiological data (i.e., on humans) nor the evidence from animal studies demonstrated causality between exposure to glyphosate and the development of cancer in humans. A supplementary document clarified that while carcinogenic glyphosate-containing formulations may exist, studies "that look solely at the active substance glyphosate do not show this effect.[12]

Joint Food and Agriculture Organization of the United Nations/World Health Organization

The World Health Organization and Food and Agriculture Organization of the United Nations Joint Meeting on Pesticide Residues issued a report in 2016 stating that the use of glyphosate

9 https://www.iarc.fr/featured-news/media-centre-iarc-news-glyphosate/

10 https://monographs.iarc.fr/wp-content/uploads/2018/06/mono112-10.pdf

11 http://www.efsa.europa.eu/en/efsajournal/pub/4302

12 http://www.efsa.europa.eu/sites/default/files/4302_glyphosate_complementary.pdf

formulations does not necessarily constitute a health risk, and giving admissible daily maximum intake limits (1 mg/kg of body weight per day) for chronic toxicity.[13]

Environmental Protection Agency

In 2017, the U.S. Environmental Protection Agency classified glyphosate as "not likely to be carcinogenic to humans."[14] The Agency's assessment found no other meaningful risks to human health when the product is used according to the pesticide label.

European Chemicals Agency

In March 2017, the Committee for Risk Assessment of European Chemicals Agency concluded that the available scientific evidence did not meet the criteria to classify glyphosate as a carcinogen, as a mutagen, or as toxic for reproduction. However, it was classified as causing serious eye damage and being toxic to aquatic life, with long-lasting effects.[15]

Australian Pesticides and Veterinary Medicines Authority

In 2017, the Australian Pesticides and Veterinary Medicines Authority reviewed the IARC monograms and other international assessments and concluded that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.[16] The Agency provides a good online overview of various studies and issues, as well as an explanation of the IARC assessment.[17]

California

On July 7, 2017, in agreement with the IARC classification, California listed glyphosate as a known carcinogen under Proposition 65 law, which would require indicating this carcinogenicity hazard on the product label of glyphosate-based herbicide products. However, in response to a legal claim by an agricultural coalition that included the National Association of Wheat Growers, Monsanto Corporation, and farmer groups, the U.S. District Court issued a preliminary injunction against this evaluation on the basis that the classification by IARC claims glyphosate only probably carcinogenic, while apparently all other regulatory and governmental bodies found the opposite, including the U.S. Environmental Protection Agency.[18]

Canada

In 2015, Health Canada's Pest Management Regulatory Agency (PMRA) released a Proposed Re-evaluation Decision document on glyphosate. The consultation document described the registration process for the use of herbicides in Canada, a summary of the science evaluated, and the reasons for the proposed re-valuation decision. Input comments were solicited. The Agency re-evaluates pesticides on a recurring basis to ensure they meet modern health and environment safety standards and continue to have value. In April, 2017, Health Canada reapproved glyphosate. The Re-evaluation Decision document summarized the Agency's final decision on glyphosate, the reasons for it, and PMRA's response to comments received. An evaluation of the available scientific information found that products containing glyphosate do

13 https://www.who.int/foodsafety/areas_work/chemical-risks/JMPR_2016_Report_May.pdf

14 https://www.epa.gov/pesticides/epa-releases-draft-risk-assessments-glyphosate

15 https://echa.europa.eu/-/glyphosate-not-classified-as-a-carcinogen-by-echa

16 https://apvma.gov.au/sites/default/files/publication/26561-glyphosate-final-regulatory-position-report-final_0.pdf

17 https://apvma.gov.au/node/13891

18 https://www.frontiersin.org/articles/10.3389/fenvs.2018.00078/full

not present risks of concern to human health or the environment when used according to the revised label directions. As a requirement for the continued registration of glyphosate uses, new risk-reduction measures were required for end-use products registered in Canada. These included a restricted-entry period of 12 hours for agricultural uses, directions for application to minimize the potential for drift into areas of human activity, environmental hazard statements, spray buffer zones, precautionary statements, and use restrictions to reduce runoff into aquatic areas.

Following Health Canada's re-evaluation decision in 2017, eight notices of objection were received. There were also public concerns about the validity of the science as indicated in the so-called “Monsanto Papers”. On January 11, 2019, Health Canada issued a statement indicating that after a thorough scientific review, objections to glyphosate use could not be scientifically supported when considering the entire body of relevant data.

APPENDIX 2. STOCKING STANDARDS AND SURVEY CHANGES RELATED TO DECIDUOUS MANAGEMENT IN BRITISH COLUMBIA

2007: Recognizing the autecology of the competition species, specifically shrub and herb compared to broadleaf species (deciduous), and the effects of these specific competitors on managed coniferous stands.

2007: Using improved free-growing decision-making tools via the quadrant method to evaluate free growing and "potentially" free-growing trees at the plot level, considering:

• site series specific competition thresholds

• competition thresholds specific to the silvics of managed crop species

This is a more refined evaluation method in the Coast, North, and South regions compared to simply evaluating competition within a 1-m cylinder with standard crop-to-brush ratios, as used in the past.

2009: Employing regionally developed brush competition assessments, specific to many BEC variants in the three Cariboo Timber Supply Areas, based on empirical data collected by silviculture researchers. This neighbourhood concept has led to a greater flexibility in crop trees being assessed as free growing when intermixed and overtopped by broadleaf competition. As well, in certain BEC variants in the Cariboo, broad leaf competition is considered as "non-deleterious", which does not affect their status as free growing.

2011: Developing new broadleaf forest health free-growing damage criteria, used to assess the acceptability of broad-leaves as free growing, given these deciduous species are specified as crop trees in an approved Forest Stewardship Plan.

2018: Expanding the "non-deleterious" definition of broadleaf competition, in conifer managed stands, to all site series within the IDFdk4 and SBPSxc BEC variants within the three Cariboo Timber Supply Areas.

APPENDIX 3. INTEGRATED PEST MANAGEMENT PRINCIPLES

Elements of Integrated Pest Management include:

1. prevention;

2. pest identification;

3. seedling and vegetation monitoring;

4. injury thresholds and treatment decisions;

5. treatment options and selection criteria; and

6. post-treatment effectiveness evaluation.

Environmental protection strategies and procedures

Prevention

Prevention of vegetation competition issues can be achieved through the following:

- **Site preparation:** The intent of site preparation is to reduce the impacts of growth-limiting factors that might inhibit seedling establishment or growth potential.
- **Planting:** Stock with high genetic worth can improve survival performance of planted seedlings. Similarly, large seedling stock is better suited to compete for light and can withstand higher brush hazards.
- **Species selection:** Species selection is based on the ecological suitability of a species to the specific site conditions in an area. Additional considerations include immediate and long-term forest health factors, future forest products, volume and value, climate change, and consistency with the Timber Supply Analysis.
- **Regeneration delay:** Seedlings that are quickly established are more likely to compete successfully with problematic vegetation. Especially on brush-prone sites, seedlings should be planted as soon as possible following harvesting.
- **Microsite selection:** Seedlings that are planted in the best microsite possible and that remain undamaged during the planting process are more likely to compete successfully with problematic vegetation.
- **Fertilization:** Fertilization treatments can improve seedling establishment and reduce the need for brushing.
- **Advanced regeneration**: Another stand establishment option is to utilize advanced growth in the understory at the time of harvesting. This could involve partial cuts such as shelterwood silviculture systems where silvics and site conditions are appropriate.

Pest identification

In the context of vegetation management, the term "pest" refers to herbaceous, shrub, and broadleaf complexes or communities that:

- inhibit plantation establishment;
- hinder optimal growth and development of crop trees;
- prevent a stand from achieving free growing;
- affect an established plantation's overall health; or
- when combined with snow, causes damage to crop trees by snow press.

Identification of potential vegetation problems starts with sound ecosystem classification from which vegetation complexes can be predicted. Post-harvest assessments and seedling monitoring can also help in identifying potential or realized brush problems.

Seedling and vegetation monitoring

Surveys and walk-throughs are scheduled throughout the plantations' development in order to ensure that stocking and brush levels are acceptable and that free-growing parameters will be achieved within the appropriate time frame. Monitoring includes post-harvest assessments, regeneration delay surveys, regeneration performance walk-throughs, and free-growing surveys.

Injury thresholds and treatment decisions

Decisions to control vegetation on a site may be based on a number of different protocols depending on regional and ecological parameters. Measures such as competition index (CI) and height-to-diameter ratio may be used to determine whether competing vegetation is negatively impacting crop trees. Crop tree status and vigour may also be evaluated based on local knowledge or percentage of crop trees that are overtopped, threatened, or above the brush.

Competition index measures competition for sunlight with regards to crop trees. It is calculated as the sum of the products of cover and height for all non-crop species within a 1.26-m radius around a crop tree, divided by crop-seedling height, and shows that growth declines with increases in the index. There is a very rapid decline in growth as CI increases from 0 to 100. At CI = 100, growth is approximately 60% of that of a seedling growing free from competition. At a CI = 150, seedlings receive 30% of the full sunlight in midsummer and would achieve approximately 45% of potential growth rates (Comeau et al., 1993). Treatment may be recommended when CI > 80.

Height-to-diameter ratio (HDR) of crop trees can indicate sturdiness. In low light conditions, conifers will put more resources toward height growth, which makes them susceptible to vegetation and snow press. Treatment may be recommended with HDR > 40 or 50, depending on species, where > 50% of stems exceed the HDR.

Treatment options

Aerial application

Broadcast treatment using a helicopter equipped with a low-pressure boom and high-volume nozzles. Variable application rates are possible. May control brush for 2–4 years.

Discretionary, non-continuous application across portions of the block can also be applied.

The most cost-effective treatment and the safest option for workers on the ground

Benefits	Limitations
• Effective control for a number of years • Minimal worker contact with chemicals • Low cost • Can treat remote, steep, slashy ground more safely than alternatives • Can treat large areas in a short time	• Less selective than other methods • Stringent application constraints • Intensive preparation and follow-up • High public profile • Residual leave trees are obstacles • Visual quality affected for years • Technically demanding • Drift can occur outside treatment areas

Backpack application

Backpack broadcast—continuous application across treatment unit with low-pressure backpack sprayer with adjustable nozzles. Variable application rates are possible. May control brush for 2–4 years. Discretionary non-continuous or spot treatment can be applied.

Benefits	Limitations
• Effective control for a number of years • Can treat blocks with standing residuals • Selective. Can apply with precision • Only small buffers needed in pesticide-free zones	• Stringent application constraints • Intensive preparation and follow-up • Requires high level of supervision • Exposure of workers to herbicide • Safety concerns about wearing heavy equipment on rough terrain • Access and water availability • Constrained by brush height • Inconsistent results from dew, rainfall, and missed spots that are difficult to detect during monitoring • Safety concerns about evacuating from remote sites • Crew availability

Cut stump

Selective application of herbicide onto a cut stump of target vegetation. Brush saw or power saw cuts the stump, and a worker applies herbicide using a backpack sprayer, squeeze bottle, or nozzle mounted on the saw. May control brush for approximately 4 years.

Benefits	Limitations
• Effective control for a number of years • Longer treatment window • Little worker exposure to herbicide • Only small buffers needed in pesticide-free zones • Low application rate	• Stringent application constraints • Intensive preparation and follow-up • Requires high level of supervision • Some exposure of workers to herbicide • Safety hazards operating power saws • Safety concerns about wearing heavy equipment on rough terrain

Motor-manual

Workers cut target vegetation with power saws or brush saws. May control herbaceous brush for less than 1 year, deciduous brush for about 2 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatments
• Public acceptance	• Safety hazards operating power saws
• Can be applied selectively	• Expensive treatment cost
• Can be used in pesticide-free zone buffers	• Relatively short window for treatment
• Not effective on herbaceous brush	• Limited availability of workers
	• Slash loads can be fire hazards, limit trafficability

Hand tools

Workers treat spots around crop trees with handheld cutters.

Girdling hardwoods to remove a continuous strip of bark around the circumference, which kills trees 2–3 years later.

Snap/hinge—partially breaking smaller stems by hand.

May control brush for less than 1 year. Girdling can control brush for about 3 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatments
• Public acceptance	• Expensive treatment cost
• Can be applied selectively	• Repetitive strain injuries are common
• Can be used in pesticide-free zone buffers	• Limited availability of workers
	• Girdling not effective on herbaceous brush

Sheep grazing

Shepherds guide a flock of sheep (1000–1500) through treatment areas, where they eat target vegetation. May control brush for 1 year.

Benefits	Limitations
• No herbicide use	• Expensive treatment cost
• Not constrained by weather	• Some crop tree damage
• Safe for workers	• Herbaceous, limited height
	• Need good access, gentle terrain, low slash.

- Risk of disease to wildlife
- Risk from predators

Mechanical site preparation

Mechanically creating favourable planting spots that mitigate limiting site factors such as cold, poorly aerated soils, competing vegetation, and frost risk. Where brush hazards are high, mounding is preferred so seedlings are elevated and receive more light, and vegetation falls away from crop trees rather than presses over them. Mounding is done with excavators or implements attached to prime movers such as skidders. May control brush for 3–5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Public acceptance	• Access and soil disturbance
• Increased soil temperature	• Site constraints—trafficability
• Facilitates planting	• Availability of contractors in the north

Prescribed burning

Prescribed burning is another form of site preparation that uses ground crews or a helicopter to apply a controlled burn. May control brush for 3–5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Good seedbed, plantable spots	• Liability and risk of escape
	• Smoke and health effects
	• Risks to workers

Treatment selection

Treatment methods for a specific site will be selected based on a number of factors, including safety concerns, timing, treatment efficacy, cost, biophysical constraints, legal constraints, political constraints, and concerns from other users and stakeholders. The following lists some of these factors:

- **Target species height**: Backpack treatments cannot be sprayed overhead. Sheep are also constrained by their ability to reach foliage and are restricted to sites with vegetation less than 1 m in height.
- **Target species diameter**: Girdling is impractical at diameters of less than 3 cm or greater than 10 cm.
- **Target species distribution**: Broadcast foliar treatments are not effective if target species are in clumps. Discretionary treatments are less appropriate if the target brush is evenly distributed.
- **Physical impediments to treatment**: Aerial treatments can be limited by residual trees, or small, irregular shaped treatment units. Ground-based treatments can be affected by steep slopes, uneven terrain, slash loading, difficult access, and remote access.

- **Buffers**: Blocks with many features that require no-treatment zones and pesticide-free zones, such as water bodies, wetlands, and roads, may have little area for herbicide treatments once all the buffers are established.
- **Timing**: Chemical treatment windows are small and require conifers that are hardening off to avoid chemical damage while target species are still succulent. Motor-manual treatment windows may overlap with fire seasons and are dependent on fire risk safety measures.
- **Special wildlife features**: Heavy browsing might reduce the need for brushing if there is little alternative browse available. Treatments that create heavy slash loads that restrict game movement may be avoided. Sheep grazing may be a poor choice in grizzly bear high-use areas.
- **Vulnerable plant species**: Vulnerable plant species are defined as those plants whose numbers are either limited or are important for browse or forage. Vulnerable plant species must be protected from broadcast treatments where identified.
- **First Nations rights infringement**: When specific information indicates that there is a higher likelihood of treatments infringing on First Nations rights on a unit, certain treatments may be considered unsuitable, or modified. For example, if consultation with a First Nation indicated that a specific site is used for berry-picking, a broadcast chemical treatment would be considered inappropriate.
- **Potential for conflict**: Some proposed treatments may result in an unacceptable risk of conflict with the public, First Nations, or other stakeholders.
- **Potential for crop tree damage**: Heavy slash loading from motor-manual treatments could mechanically damage crop trees. It can be difficult to spot crop trees in dense vegetation, which can result crop tree damage. Brushing can increase the risk of root rot spreading. Slash loading or dead stems can also create fire risks.
- **Availability of crews**: It is increasingly difficult to attract workers to the silviculture industry, and brushing is onerous physical work. Safety is also a factor, as higher numbers of injury claims are associated with higher claim payments for brushing and weeding. Fewer people are engaging in this sector. The area manually brushed, 11,600 ha in 2018, would have to double to treat the sprayed area, so workforce availability would be limiting.

Post-treatment effectiveness evaluation

Efficacy is checked for the amount of target vegetation removed, current level of competition, missed areas, crop tree damage, environmental impacts, and scheduling of next entry.

Environmental protection strategies and procedures

Operational procedures and standards for herbicide applications (including herbicide transportation, storing, mixing, loading, disposal) and the environmental safeguards in place regarding herbicide field application, including considerations regarding:

- strategies to protect community watersheds and other domestic water sources
- strategies to protect fish and wildlife, riparian areas, and wildlife habitat
- pesticide-free zones
- species at risk

- strategies to prevent herbicide treatment of food intended for human consumption
- pre-treatment inspection procedures for identifying treatment area boundaries
- weather monitoring and strategies
- procedures for maintaining and calibrating herbicide application equipment

GLOSSARY

BEC	Biogeoclimatic Ecosystem Classification
FLNRORD	B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FPPR	Forest Planning and Practices Regulation
FSP	Forest Stewardship Plan
IPMR	Integrated Pest Management Regulation
PMP	Pest Management Plan
PMRA	Health Canada Pest Management Regulatory Agency
RESULTS	Reporting Silviculture Updates and Land Status Tracking System
sph	stems per hectare



info@fpinnovations.ca
www.fpinnovations.ca

OUR OFFICES

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
(514) 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
(604) 224-3221

Québec
1055 rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
(418) 659-2647

BRIEFING NOTE FOR INFORMATION

DATE:	December 16, 2019
PREPARED FOR:	Honourable Doug Donaldson, Minister of Forests, Lands, Natural Resource Operations and Rural Development
ISSUE:	FPInnovations' Glyphosate Use in BC Forestry, Review Report

BACKGROUND:

- Glyphosate is an herbicide used by forest managers to reduce broadleaf competition of conifer plantations to assist achievement of free-to-grow status.
- Glyphosate use is a controversial issue with the public, particularly related to recent claims of habitat impacts and the decline in moose populations.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee comprised of staff from Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) and Environment and Climate Change (ENV) was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was contracted to assess current peer reviewed forest science and best practices related to glyphosate use primarily in the context of the current value-set that applies to forest management throughout BC (e.g., biodiversity, First Nations, climate change, soil and water, etc.).
- This note provides a brief summary of FPI's report and sets out next steps, including internal and external communication.

DISCUSSION:

- Based on an initial assessment of the ~50-page report (ref. Appendix 1), FPI reports that the risk of glyphosate and its metabolites[1] on the environment is minimal when the herbicide is applied according to the product instructions (label). Further, it confirms that species richness and diversity of flora and fauna remain in the range of natural variation, and that any changes to these communities when glyphosate is used is transient.
- Glyphosate is one of many vegetation management tools available to forest managers. Glyphosate, while very cost-effective, is declining in use relative to the forested area harvested each year. In 2018, ~ 11,000 hectares of Crown land in BC were treated with glyphosate representing 7 percent of the Crown area harvested that year, most of which was in the Omineca Forest Region.
- Further, the FPI report also indicates that contrary to current public perceptions, the data indicates that parts of BC have shown a significant increase in mixed deciduous stands over the years due to previous harvesting activity; even in stands that have been previously treated with glyphosate. Deciduous trees still account for 15-20 percent of the stems per hectare at free growing.

[1] A metabolite refers to the product that remains after a chemical has broken down, digested or otherwise processed.

- The FPI report also makes a series of recommendations related to opportunities to improve research and data; particularly with respect to glyphosate persistence in plants, impact on soil micro-organisms, wildlife forage and fire behaviour.
- The FPI report also includes recommendations related to the opportunities to improve two-way communication with First Nations and the public related to glyphosate use.

NEXT STEPS:

s.13

Attachments:

1. Briefing note "*Summary of FPInnovations Glyphosate Review Report*" (CLIFF 252256).
2. Review of Glyphosate Use in BC Forestry (FPI, Dec. 11, 2019).

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
MO		
DMO		
ADM	DN	December 19, 2019
ED	SB	December 16, 2019
Program Dir/Mgr.	SH	December 13, 2019

Begon, Stacey FLNR:EX

From: Hedges, Shawn FLNR:EX
Sent: November 5, 2019 3:19 PM
To: Mullan, Jonathan M ENV:EX; Berg, Shane FLNR:EX; Zacharias-Homer, Christa ENV:EX; MacDougall, Julie FLNR:EX; Psyllakis, Jennifer FLNR:EX; Bedford, Lorne FLNR:EX; Hughes, Neil FLNR:EX; Gordon, Steve M FLNR:EX
Subject: Re: glyphosate deliverable
Attachments: Glyphosate 19.10.29 (Nov 5_19 Comments_Edits).docx

Thank you Jonathan.

All, I have re-ready the draft report and have added a few more comments and edits to Jonathan's recent contributions.

I look forward to reviewing this with you tomorrow (i.e., Wednesday) at 4:30 pm.

Shawn

From: "Mullan, Jonathan M ENV:EX"
Date: Monday, November 4, 2019 at 1:24 PM
To: Shawn Hedges , "Berg, Shane FLNR:EX" , "Zacharias-Homer, Christa ENV:EX" , "MacDougall, Julie FLNR:EX" , "Psyllakis, Jennifer FLNR:EX" , "Bedford, Lorne FLNR:EX" , "Hughes, Neil FLNR:EX" , "Gordon, Steve M FLNR:EX"
Subject: RE: glyphosate deliverable

Hi Shawn,

I have inserted a few comments for the contractor to consider clarifying the IPM regulation requirements and a number of suggestions for providing additional context.

Jon Mullan

From: Hedges, Shawn FLNR:EX
Sent: October 31, 2019 4:26 PM
To: Berg, Shane FLNR:EX ; Zacharias-Homer, Christa ENV:EX ; MacDougall, Julie FLNR:EX ; Psyllakis, Jennifer FLNR:EX ; Mullan, Jonathan M ENV:EX ; Bedford, Lorne FLNR:EX ; Hughes, Neil FLNR:EX ; Gordon, Steve M FLNR:EX
Subject: Re: glyphosate deliverable

Colleagues, attached a redlined copy of the draft report after my initial read (I'll read it again tomorrow). Ignore my yellow highlighting…my suggested edits and commentary should be self-explanatory and are generally minor in nature.

In summary, and based on first impressions, I'm pleased with the product. Maybe a 7 or 8 on my "satisfaction scale", but perhaps I'm a soft grader?

Meeting/conference call request to discuss further as a team Wednesday Nov. 6th from 4:30-5:30 pm will be sent shortly.

I would like to be able to send some consolidated comments back to FPI via Ken Byrnes by next Friday Nov. 8th if possible.

Also, as a reminder, we're out of money on this one so if you have major concerns we should talk about them but you may have to hold your nose at this late stage of the contract.

Shawn

From: Shawn Hedges <Shawn.Hedges@gov.bc.ca>
Date: Wednesday, October 30, 2019 at 8:55 AM
To: "Berg, Shane FLNR:EX" <Shane.Berg@gov.bc.ca>, "Zacharias-Homer, Christa ENV:EX" <Christa.ZachariasHomer@gov.bc.ca>, "MacDougall, Julie FLNR:EX" <Julie.MacDougall@gov.bc.ca>, "Psyllakis, Jennifer FLNR:EX" <Jennifer.Psyllakis@gov.bc.ca>, "Mullan, Jonathan M ENV:EX" <Jonathan.Mullan@gov.bc.ca>, "Bedford, Lorne FLNR:EX" <Lorne.Bedford@gov.bc.ca>, "Hughes, Neil FLNR:EX" <Neil.Hughes@gov.bc.ca>, "Gordon, Steve M FLNR:EX" <Steve.Gordon@gov.bc.ca>
Subject: FW: glyphosate deliverable

Glyphosate steering committee, I'm forwarding you the attached polished draft report I received yesterday from the FPI folks.

Please review the report and be prepared to discuss further during a meeting/call I will set up for next week.

Also, until we've had a chance to discuss this as a team I discourage you from circulating this draft outside this group.

Shawn

From: James Hunt <james.hunt@fpinnovations.ca>
Date: Tuesday, October 29, 2019 at 3:46 PM
To: Shawn Hedges <Shawn.Hedges@gov.bc.ca>
Cc: Ken Byrne <ken.byrne@fpinnovations.ca>, Pamela Matute <pamela.matute@fpinnovations.ca>
Subject: glyphosate deliverable

Shawn,

Here it is.
Can you please distribute this draft for review? I will send it to Chris Edge and Nelson Thiffault, the NRCAN researchers as discussed.
We'll do a final edit once we have review comments.
Thank you very much for your valuable assistance and direction. Also for your patience as we dealt with our computer challenges.

Cheers,

Jim

JIM HUNT, RPF
Science Leader
Fibre Supply

FPInnovations
2665 East Mall, Vancouver, BC, V6T 1Z4
T 604-222-5618 | **C** 604-219-8487
james.hunt@fpinnovations.ca

FPInnovations

info@fpinnovations.ca
www.fpinnovations.ca

REVIEW OF GLYPHOSATE USE IN BC FORESTRY

BRITISH COLUMBIA

Jim Hunt, Lead Scientist

Pamela Matute, Researcher

FPInnovations

Current glyphosate use in BC forestry was reviewed including peer-reviewed forest science on the impacts of glyphosate use on forests as well as input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishment of forest stands post-harvest.

Project number: 301013763

ACKNOWLEDGEMENTS

This project was contracted by the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

APPROVER CONTACT INFORMATION
Shawn Hedges
Director, Sustainability and Forestry

shawn.hedges@gov.bc.ca

REVIEWERS
Ken Byrne, Manager, Fibre Supply

AUTHOR CONTACT INFORMATION
Jim Hunt
Lead Scientist, Fibre Supply
james.hunt@fpinnovations.ca
(604) 222-5618

Disclaimer to any person or entity as to the accuracy, correctness, or completeness of the information, data, or any analysis thereof contained in this report, or any other recommendation, representation, or warranty whatsoever concerning this report.

Follow us

Table of contents

Executive Summary 1
1 Introduction 3
2 Use of Glyphosate in BC Forests 4
2.1 Regulatory Framework 4
2.1.1 Free Growing 4
2.1.2 Herbicides 5
2.2 Why is Glyphosate Used? 6
2.2.1 Site Preparation 7
2.2.2 Plantation Survival 7
2.2.3 Crop Tree Productivity 7
2.2.4 Invasive Species 7
2.3 How is glyphosate used? 8
2.3.1 Area treated 8
2.3.2 Glyphosate Use at the Stand-Level 12
2.4 Treatment Costs 14
3 Impact of glyphosate use on non-timber values 15
3.1 Biodiversity 15
3.1.1 Broadleaf Tree Species 15
3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide 15
3.1.1.2 RESULTS Analyses 16
3.1.2 Non-Target Plant Communities 18
3.1.3 Aquatic Organisms 19
3.1.4 Wildlife 20
3.1.4.1 Toxicity 20
3.1.4.1 Forage quality and quantity 21
3.2 Soil and Water Quality 21
3.2.1 Glyphosate/AMPA fate in soils 21
3.2.2 Soil micro-organisms 22
3.2.3 Glyphosate/AMPA fate in water 22
3.3 Climate Change 23

3.4 Wildfire 24
3.5 First Nations 24
3.6 Public Use 25
4 Impacts on Timber Supply 26
4.1 s.13 27
5 Recommendations 28
6 Conclusions 29
6 References 31
Appendix 1. International Assessments 43
Appendix 2. Stocking Standards and Survey Changes Related to Deciduous Management in BC 46
Appendix 3. Integrated Pest Management Principles 47
Glossary 54

EXECUTIVE SUMMARY

FPInnovations was contracted by the Office of the Chief Forester to undertake a review of current glyphosate use in BC forestry including peer-reviewed forest science on the impacts of glyphosate use on forests as well as input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishment of forest stands post-harvest. The report will inform future policy development and research needs with the main objective to promote the establishment of healthy and diverse forests.

The herbicide glyphosate is one of many vegetation management tools available to forest managers. As a tool for vegetation control, it is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. It is very effective because it is easily translocated within the target plant, usually killing it and reducing the brush hazard for multiple years after a single application, unlike other motor-manual vegetation control methods. Glyphosate application may target aggressive competition from broadleaved trees, shrubs and herbaceous vegetation.

Roughly 11,000 ha of crown land were treated with glyphosate in BC for silviculture in 2018. Total area treated with glyphosate was 7% of the area harvested in 2018 on BC crown land, and less than 0.5% of the area with outstanding reforestation obligations. In 2018, most (73%) of the glyphosate application occurred in the Omineca Natural Resource Region. Of all biogeoclimatic zones, the Sub-Boreal Spruce zone saw the most glyphosate use (76%). Glyphosate was primarily applied aerially (86%) while the remainder 14% was treated using ground-based methods.

Public concerns over the impacts of glyphosate use on the ecosystem is currently growing, particularly regarding ecosystem changes resulting from the control of broadleaf trees such as trembling aspen. A RESULTS (Reporting Silviculture Updates and Land Status Tracking System) analysis of deciduous stand components at free growing showed that in the Omineca, where most of the glyphosate application takes place, deciduous components accounted for 15-21% of the stand density in sites that were previously treated with glyphosate. Data also shows that in the BC interior, mixed deciduous stands have been increasing over time as a result of forest management activities.

A summary of the many studies regarding the impact of glyphosate on forest soils, water, non-target plant communities, and wildlife is presented. While impacts can vary with site characteristics, research has shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes to these communities are related to changes in vegetation structure and are transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. Recent research has found low but unexpected levels of glyphosate residue in plants one year following treatment, which may have implications on wildlife forage quality, plant physiology and traditional food and

medicine plant harvesting. While residue levels were non-toxic to humans and wildlife, little is known about their effect on forage quality and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

Glyphosate remains an important tool for establishing conifer or conifer-deciduous mixed stands and ensuring future timber supply. Glyphosate bans in other jurisdictions in Canada have resulted in significant struggles to meet timber objectives in the land base, highlighting glyphosate's important role in maintaining conifer productivity. Forest management in BC seeks to balance all values ascribed to the forest with the overarching objective of establishing and maintaining healthy and diverse forests. While more research is recommended on the identified knowledge gaps, glyphosate needs to be considered in the context of these values and objectives, and with perspective regarding the amount of area treated, the apparent transient effects on the site's ecology, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels.

1 INTRODUCTION

Public pressure to reduce the use of glyphosate has been increasing in British Columbia and other jurisdictions. In response, the Office of the Chief Forester for BC Ministry of Forests Lands, Natural Resource Operations and Rural Development's (FLNRORD) ~~of BC~~ contracted FPInnovations to undertake a review of current peer-reviewed forest science and best practices on glyphosate use in the BC forestry. Input from stakeholders was also solicited. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered[1]. The report will inform future policy development and research needs with the main objective to promote the establishment of healthy and diverse forests. s.13

s.13

s.13

Successful regeneration of forests after timber harvesting often requires control of competing vegetation which may cause mortality or reduced growth of established seedlings. Several vegetation management alternatives exist for this purpose, including s.13

s.13

s.13

Glyphosate-based herbicides are the most widely used in the world, largely due to their effectiveness, their safety for non-target species and the environment, and the development of glyphosate tolerant agricultural crops (Edge et al. 2014). Several factors support the use of this herbicide in forestry applications in BC:

- Ability to translocate within treated plants and control resprouting of perennial weeds;
- Generally favourable environmental profile, including binding in soils and rapid biodegradation in most soils, water and sediments;
- Specific mechanism of action, inhibiting an enzyme found only in plants;
- Low toxicity to animals; and
- Minimal impact on forest ecosystems (Rolando et al 2017).

s.13

1 See Forest Planning and Practices Regulation Part 2, Division 1.

2 USE OF GLYPHOSATE IN BC FORESTS

2.1 Regulatory Framework

2.1.1 Free Growing

In BC, timber harvesting in public forests is regulated such that any harvested area must be reforested to an acceptable standard of free growing. The *Forest Range and Practices Act*[2] (FRPA) (sec 1) defines "free growing" as "*a stand of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees*". A free growing stand is expected to contribute to landscape objectives and to a sustainable long-term fibre supply.

Formatted: Font: Italic

The Forest Planning and Practice Regulation~~3~~ (FPPR) (Sec 44) addresses obligations to produce a free growing stand that meets applicable stocking standards approved in a Forest Stewardship Plan (FSP) by specified dates. Stocking standards are regulatory tools that ensure that the re-establishment of a forest stand post-harvest is aligned to large-scale objectives for the land base as set out in FSPs. Stocking standards specify regeneration requirements such as suitable tree species for the site, stand density, spacing, free growing height and ratio of crop tree height to surrounding competing vegetation.

Sec 46.11 of the FPPR indicates that these silvicultural obligations must be fulfilled on each hectare within the net area to be reforested, unless otherwise specified in an FSP. Mappable areas that do not meet stocking standards should not exceed 2 ha or 5% of the Standard Unit (SU) area. Under FPPR section 97.1, an obligation holder may be relieved of the obligation to meet stocking standards if they can prove that obligations have been met to the extent that is practicable.

Sec 26 (5) of the FPPR ~~Sec 26 (5)~~ also provides a mechanism to develop stocking standards in an FSP that are not consistent with current timber supply assumptions. The review test for sec~~tion~~ 26 (5) requires the Delegated Decision Maker to be satisfied that the regeneration date and stocking standards are reasonable, having regard for future timber supply and the set values ascribed to forest land.

Free growing surveys are the tool by which forest managers measure whether a stand meets free growing obligations. Survey methods, including quantification of shrub and broadleaf competition, are described in the Silviculture Surveys Procedures Manual[4]

Stocking standards and related guidance have evolved since the 1990s and continues to evolve to incorporate current understanding of resource issues (e.g. broadleaf species) and their

2 http://www.bclaws.ca/Recon/document/ID/freeside/00_02069_01

~~3 http://www.bclaws.ca/civix/document/id/lc/statreg/14_2004~~

4 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

impact on timber supply and other forest values. A summary of these developments is described in Appendix 2.

2.1.2 Herbicides

Health Canada's Pest Management Regulatory Agency (PMRA)[5] is responsible for regulating pesticide use in Canada to ensure they pose minimal risk to human health and the environment. Under authority of the Pest Control Products Act, Health Canada:

- registers pesticides after a stringent, science-based evaluation that ensures any risks are acceptable;
- re-evaluates the pesticides currently on the market on a 15-year cycle to ensure the products meet current scientific standards; and
- promotes sustainable pest management.

s.13

s.13

The *Integrated Pest Management Act* (IPMA) and Regulation[6] (IPMR) sets out the requirements for the use and sale of pesticides in BC[7]. The BC Ministry of the Environment and Climate Change Strategy (ENV) promotes Integrated Pest Management (IPM) and environmental stewardship and ensures compliance with the IPM Act and Regulations. Large scale pesticide programs (i.e. >20 ha/year of treatment area) that require IPM must have a confirmed Pest Management Plan (PMP). PMPs document how the standards set in the IPMR will be implemented regarding

s.13

s.13

Formatted: Font: Italic

IPM is a process for managing pest populations. In a forestry context where competing vegetation is considered as a pest or weed, the following integrated vegetation management elements would apply:

- Planning and managing ecosystems to prevent organisms from becoming weeds;
- Identifying weed problems and potential weed problems;
- Monitoring populations of weeds and weed complexes;
- Using injury thresholds[8] in making treatment decisions;
- Select pest treatment methods based on:

5 https://www.canada.ca/en/health-canada/corporate/about-health-canada/branches-agencies/pest-management-regulatory-agency.html

6 https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management/pesticide-use/regulations-consultations

7 https://www2.gov.bc.ca/assets/gov/environment/pesticides-and-pest-management/business-and-industry/forestry_review.pdf

[8] The injury threshold is the level at which pest numbers are high enough to cause unacceptable injury or damage.

- Consideration of practical alternatives to herbicide use,
- Protection of human health and the environment; and

- Evaluating the effectiveness of weed management treatments.

Herbicides are rarely the only integrated vegetation management method used and are generally used in conjunction with other methods. Examples of best practices for implementing integrated vegetation management are included in Appendix 3.

2.2 Why is Glyphosate Used?

Managing competing vegetation is an essential part of reforestation efforts after forest harvesting. In B.C., vegetation management focuses on highly aggressive herbaceous complexes such as fireweed or bluejoint grass, and competitive deciduous trees such as red alder, broadleaf maple and trembling aspen. Targeted vegetation control is used for two main reasons in silviculture:

Commented [MOU9]: Used as "BC" (not "B.C.") elsewhere

- to maintain plantation survival, and
- to meet free growing obligations that ensure stand productivity and sustainable future timber supply.

s.13

Depending on the developmental stage of a plantation and its brush complex, glyphosate may be used to: clear a planting site of pre-established brush, to reduce seedling competition in order to ensure plantation survival, or to meet free-growing requirements that ensure long-term productivity and timber supply, particularly where specific timber species and outcomes are being managed for.

2.2.1 Site Preparation

s.13

2.2.2 Plantation Survival

Plantations on sites with aggressive competing vegetation complexes can fail within a year without effective vegetation management. In these cases, interventions are often needed to avoid excessive seedling mortality and plantation failure (Comeau and Harper, 2009; Biring et al. 2003; Comeau et al., 1999). This application of glyphosate is particularly important with herbaceous vegetation complexes for which mechanical cutting is not effective, such as bluejoint reed grass (*Calamagrostis canadensis*). Bluejoint reed grass is a serious competitor in northeastern BC, where it often colonizes sites after harvest forming thick colonies that can prevent establishment of shrub and tree species for upwards of 25 years if left uncontrolled (Dunbar et al, 2011). Glyphosate application on these sites can suppress the growth of competitive vegetation ~~for~~ enabling tree seedlings to become established.

2.2.3 Crop Tree Productivity

s.13

s.13 A single application of glyphosate during the first few years after planting in high-brush sites has been shown to effectively improve conifer growth 9 to 20 years later in a wide range of plant communities in various ecosystems in ~~British Columbia~~BC (Harper et al. 1997a, b; Whitehead and Harper 1998; Biring et al. 1999, s.13 Biring and Hays-Byl 2000; Simard 2001; Harper et al. 2005; Boateng et al. 2006; Macadam and Kabzems 2006). There is substantial variation in the magnitude of reported growth gains as they are dependent on type, intensity and duration of vegetation competition; in certain cases, the effects have been found to be significant but can also be short-term (Comeau et al., 1999; Heineman et al., 2005; Comeau and Harper, 2009).

Commented [MOU12]: ?

2.2.4 Invasive Species

While the focus of this report is on use of glyphosate in BC silviculture, glyphosate may also be used in forests to control the spread of noxious and invasive weeds across the province. FRPA sec 47 indicates that a person carrying out a forest or range practice must carry out measures to prevent the introduction or spread of prescribed species of invasive plants as listed in the invasive species regulation. The BC Weed Control Act requires all land occupiers to control the spread of noxious weeds on their land or premises.

s.13

s.13

2.3 How is glyphosate used?

2.3.1 Area treated

s.13

Data from the RESULTS s.13
database s.13

s.13 11,000 ha of crown land were treated with glyphosate for silviculture in 2018[11] with 86% sprayed aerially and 14% sprayed using ground-based methods (Figure 1). s.13

s.13

s.13 The area sprayed in 2018 was 0.044% of the 25 M ha available for harvesting in BC and 0.44% of the tenured area on crown land that has an outstanding reforestation obligation.

s.13

9 https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/invasive-species/pest-management/2019_herbicide_summary_for_control_of_knotweeds_on_crown_lands.pdf

10 https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-reporting-results

[11] This includes aerial and ground-based brushing and site preparation treatments excluding 'basal spray' and 'stem bark spray' silviculture methods which do not apply to glyphosate. It may include some triclopyr application that was reported as Backpack treatment method. Private land is not included.

s.13

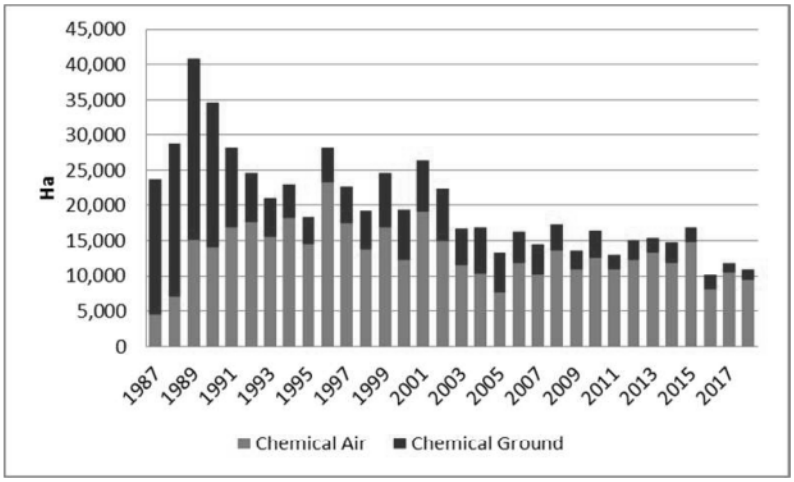


Figure 1. Area sprayed with glyphosate for silviculture in BC.

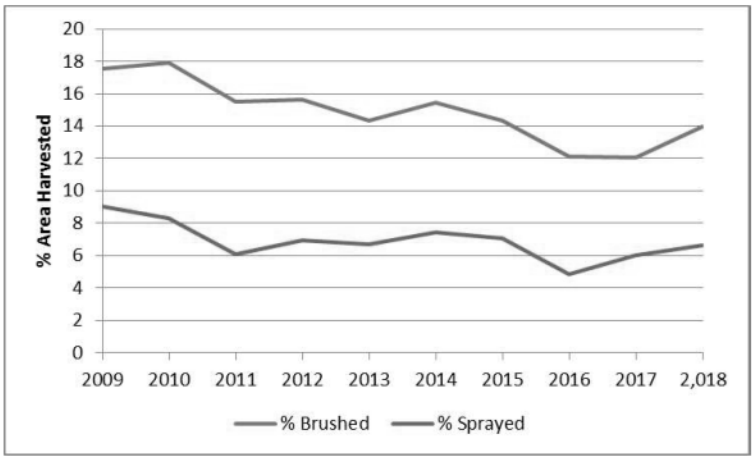


Figure 2. The percentage of harvested area that is brushed with alternative methods and sprayed with glyphosate.

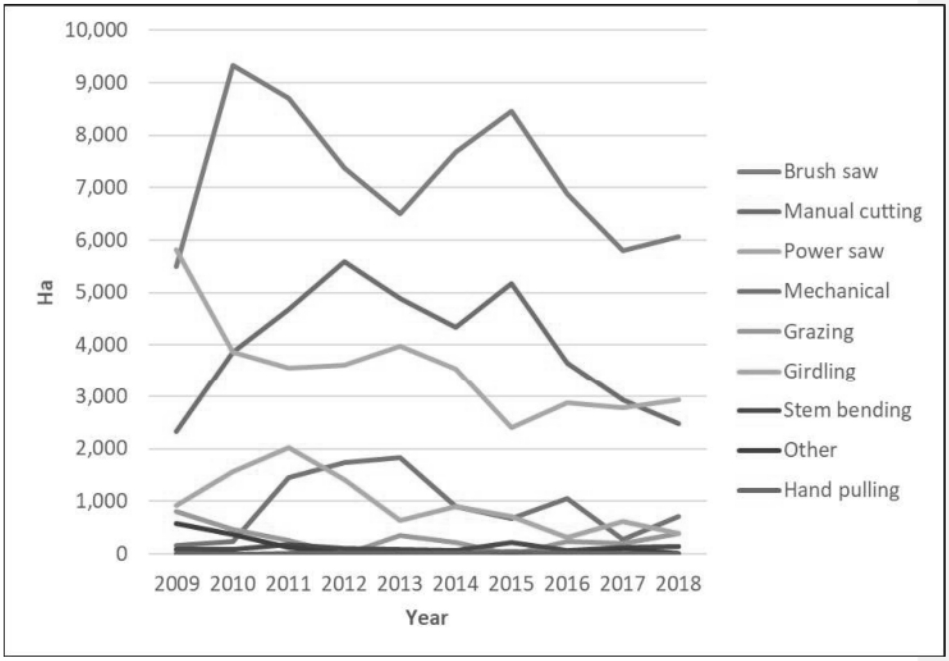


Figure 3. Area brushed with non-chemical methods.

Most of the spraying occurred in the Omineca Natural Resource Region (73%) followed by the Northeast Region (11%) (Table 1). The Prince George Timber Supply Area (TSA) comprised 68% of the total provincial area sprayed with glyphosate in 2018. Aerial applications made up 96% of the spray programs in those Regions. Small aerial programs also occurred in Thompson-Okanagan and South Coast Regions. Small ground-based programs occur in all regions with the largest occurring in the South Coast Region. The proportions of area harvested that were sprayed with glyphosate range from 11-15% for the South Coast, Northeast and Omineca regions, while the remaining regions in the province were less than 3% of the harvested area (Table 1).

Table 1. Area sprayed with glyphosate by Natural Resource Region (ha) in 2018.

s.13

The biogeoclimatic (BGC) zones (Meidinger and Pojar 1991) where most of the glyphosate application occurred are the Sub-Boreal Spruce (76%) and Boreal White and Black Spruce (9%) zones (Table 2).s.13 The drier SBS subzones (dry warm (dw) and moist cool (mk)) are dominated by aspen while the wetter subzones (wet cool (wk) and very wet cool (vk)) are dominated by herbaceous vegetation.

Table 2. Area sprayed with glyphosate by BGC zone (ha) in 2018

s.13

s.13

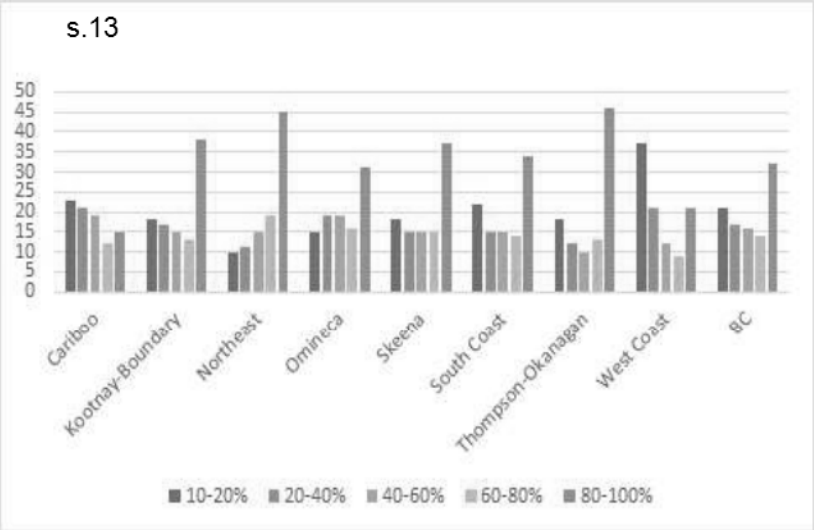
2.3.2 Glyphosate Use at the Stand-Level

Glyphosate is generally used in a targeted portion of the total reforestation area, as opposed to covering entire cutovers. s.13

s.13

[12] This analysis included blocks that were treated with herbicide one time only

s.13



s.13

In contrast with agriculture and other common land uses where areas are sprayed repeatedly,
s.13
s.13 The percentage of blocks treated more than twice was 32% for ground-based and 11% for aerial in BC. The Coast regions had a higher proportion of retreatments s.13
s.13

s.13

	Ground			Aerial		
	Number of Treatments					
	1	2	>2	1	2	>2
	%			%		
Cariboo	74	20	6	83	16	1
Kootenay	44	42	14	100	0	0
Northeast	64	25	12	53	30	17
Omineca	89	10	1	68	24	8
Skeena	79	11	10	70	15	15
South Coast	41	29	30	79	21	0
Thompson	75	17	8	45	33	22
West Coast	24	19	58	63	25	11
BC	47	21	32	65	25	11

Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species. Commonly targeted vegetation complexes in the SBS, where most of the glyphosate application takes place, are trembling aspen, mixed shrub, fireweed and wet alder. The BWBS zone is dominated by aspen/poplar and reed grass complexes (Comeau et al, 1996).

Target species are indicated on brushing prescriptions developed from operational surveys. A licensee in the Prince George region has indicated that 53% of the 2018 aerial spray area targeted aspen while 47% targeted herbaceous/shrub competition. Aggregated data of which complexes are targeted the most by glyphosate application is currently lacking. More work is required to understand how glyphosate use is distributed amongst particular vegetation complexes or species to understand how and why glyphosate is used, and what the impact of not using glyphosate would be.

2.4 Treatment Costs

Treatment costs vary considerably depending on location, access, treatment intensity, availability of crews and equipment, logistics, etc. BCTS and ~~Licensees~~ licensees reported that manual treatments ($700-$1,200/ha) are twice the cost of glyphosate treatments ($300-$500/ha) and require at least two treatments. The cost of achieving free growing on a site that needs vegetation control ranges from $900-$2,100/ha more when using manual treatments. An example of treatment costs to attain free growing with and without glyphosate in the Prince George region was provided by BCTS s.13 Assuming the s.13 example is representative and applying an average cost difference of $1,400/ha to the 11,000 ha area that was sprayed in 2018, the cost of not using glyphosate for silviculture is estimated at $15.4 M per year.

s.13

s.13

s.13 costs are an important consideration - safety, access, crew availability, treatment windows and various operational factors also affect the selection of treatment options discussed in Appendix 3.

3 IMPACT OF GLYPHOSATE USE ON NON-TIMBER VALUES

s.13

3.1 Biodiversity

The FPPR indicates the objective set by the BC government for wildlife and biodiversity at the landscape level is, without unduly reducing the supply of timber from British Columbia's forests and to the extent practicable, to design areas on which timber harvesting is to be carried out that resemble, both spatially and temporally, the patterns of natural disturbance that occur within the landscape.

3.1.1 Broadleaf Tree Species

Mixedwood forests provide various ecological, social, and non-timber values; have significant value in shaping forest ecology, stand structure, and function; and exert a strong influence on forest diversity and resilience (Harper 2014)s.13

s.13

3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide

On sites where it exists pre-harvest, aspen regenerates aggressively from suckering after a stand-replacing event such as fire or harvesting (Frey et al. 2003). This is particularly the case in the boreal and sub-boreal mixedwoods that make up large portions of Central and Northeastern BC, where research has shown that in order to establish a conifer crop, vegetation management is often required to counter the suckering of aspen following harvest (Wood and von Althen 1993; Cole et al. 2003; Pitt and Bell 2005; Boateng et al. 2006).

s.13

While those studies focused on deciduous composition within herbicide-treated areas, it's important to note that glyphosate is not generally applied to entire harvest units (see section 2.3.2), and that the total elimination of competitive vegetation is not a silvicultural objective of

conifer-release programs (Bell and Newmaster 2002). In B.C., vegetation management treatments, including glyphosate application, are carried out only in the portions of a harvest unit where they are deemed necessary for conifer survival or to meet free-growing stocking standards in each standard unit as per Sec 46.11 of the FPPR.

3.1.1.2 RESULTS Analyses

A 2008 Forest and Range Evaluation Program (FREP) review of species diversity pre- and post-harvest in B.C. found that the amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods (BCMFLNROR 2008). Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing, a 3,000% increase.

Commented [MOU23]: Did you mean to say FLNRORD?

An up-to-date RESULTS query of stand composition for all stands declared free growing following herbicide treatment (aerial and ground-based) was prepared for this report by FLNRORD. s.13

s.13

This corresponds to 15% and 16% broadleaf components (by stem density).

In the Northeast and Omineca Regions, where most herbicide treatments take place, the average number of deciduous stems/ha at free growing following aerial herbicide treatments were 864 and 445 stems/ha, or 27% and 15% of the total stand species composition s.13

s.13

In general, ground-based application resulted in a slightly higher number and percentage of deciduous stems at free growing compared with aerial application for most regions. s.13

s.13

s.13

s.13

s.13

3.1.2 Non-Target Plant Communities

3.1.2.1 Diversity of plant communities

A review of 12 studies by Sullivan and Sullivan (2003) found that species richness and diversity of nontarget vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies report that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment (Sullivan et al 1998a, Freedman et al., 1993; Lautenschlager and Sullivan 2002, Bell and Newmaster 1998; Hawkins et al., 2013; Comeau and Fraser, 2018). In many cases, herbaceous vegetation abundance, diversity and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank (Sullivan and Sullivan, 2003; Kabzems and Harper, 2015).

While broadcast aerial spraying of glyphosate is sometimes seen as a blunt vegetation management tool, studies have found that it doesn't target all vegetation equally. On sites with a vertical vegetation structure (comprised of aspen, shrubs, and forbs), one study found that the majority of the spray was deposited in the aspen canopy (68% of the nominal application rate), while shrubs and herbs captured approximately 25% and 12% of the nominal application rate, which may further help explain their quick recovery (Thomson et al 1997).

Only two of the twelve studies analyzed by Sullivan and Sullivan (2003) observed an overall reduction in species richness of shrubs after glyphosate application (Santillo et al., 1989a; Sullivan et al., 1988). Santillo et al. (1989) found that species richness was decreased by 50% and

Commented [MOU24]: ?

30% for shrubs and herbs respectively one year after treatment and continued to be lower in the treatment units after three years. The control sites in this study however were at a different successional stage than the glyphosate treatment units (Santillo et al., 1989a). Sullivan et al. (1988) likewise observed a reduction in shrub species richness 5 years after treatment.

s.13

3.1.2.1 Persistence of glyphosate/AMPA in plant tissue

Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions (Gomes et al. 2014) due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels s.13 s.13 in some surviving perennial forest plants for at least 1 year (Wood 2019). Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality, however some translocation into shoots and fruit was observed in select plants (Wood 2019). s.13 s.13

s.13

s.13

s.13

3.1.3 Aquatic Organisms

Amphibian populations are declining around the world (Houlahan et ~~at~~ al. 2000), and chemical contaminants released to aquatic environments have been listed as the second most important threat to amphibians after habitat loss (Edge et ~~at~~ al. 2011). s.13 s.13

s.13

Numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development (Edge et al. 2012, Lanctot et al. 2013, Edge et al. 2014b), the expression of genes related to larval development (Lanctot et al. 2013), or juvenile amphibian survival (Edge et al. 2011, 2013). This is likely due to the short (but environmentally realistic and relevant) exposure duration (generally less than 96 hours) and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands (Edge et al. 2012, 2014b, Baker et al. 2016).

Formatted: Highlight

A watershed level study in coastal BC found temporary stress effects and minor mortality (2.6%) in caged coho salmon smolt in an experimentally over-sprayed tributary and the main stream below the sprayed area immediately post glyphosate application. No acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident coho (Legris and Couture, 1991; Feng et al. 1990; Reynolds et al., 1993). Similarly, no effects on

growth, behaviour or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment (Morgan and Kiceniuk, 1992).

s.13

3.1.4 Wildlife

3.1.4.1 Toxicity

Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates (Durkin et al., 2003; Giesy et al. 2000; PMRA, 2015). Some uncertainty remains in the literature regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage. While observed residue levels were non-toxic to mammals, the effects of chronic sub-lethal exposure to mammals are not yet well-understood and require more research (Wood, 2019; Mesnage et al. 2015; Kissane and Sheppard, 2017)

Formatted: Highlight

Effects on terrestrial wildlife communities, like in aquatic ecosystems, are primarily linked to the changes in vegetation cover and forage quality. As such, species responses are highly variable and reflect individual habitat preferences. Studies on wildlife response to habitat alteration from glyphosate application have shown no effect, short-term negative effects and positive effects on different wildlife species (Guynn et al 2004). All in all, studies suggest that species richness and diversity of small and large mammals s.13 songbirds and invertebrates remain within the range of natural variation and that changes are transient (Sullivan and Sullivan 2003).

3.1.4.1 Forage quality and quantity

Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline (Kuzyk et al. 2018).

s.13

s.13 The long-term impact of glyphosate use on habitat selection by moose is not well understood however. Biring et al. (1999) reported decreased forage abundance and use 12 years after glyphosate application in a BWBS site. However, Newton reported a 46% decrease in forage the year following glyphosate application, but a 660% increase in forage at year 8 compared to the control (Newton et al. 1989), and some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls (Raymond et al. 1996; Eschholz et al. 1996). These impacts must also be considered in relation to the area treated annually and its distribution over the landscape (Lautenschlager and Sullivan 2002).

The effects of glyphosate's chelating properties on forage quality and nutrient availability are poorly understood.s.13 properties of glyphosate allow it to bind macro- and micronutrients (in particular iron, manganese, zinc, copper and nickel) which can s.13 impact uptake and availability in plants treated with glyphosate (Mertens et al., 2018). These micronutrients are particularly important to ungulates such as moose, whose sensitivities to mineral imbalances (in particular Cu) have been implicated in moose population decreases in Alaska, Sweden and Minnesota (Custer et al., 2004; Flynn et al., 1977; O'Hara et al., 2001; Frank et al., 1994).

Studies on nutrient uptake by surviving plants in agricultural settings after glyphosate application has provided contradictory accounts (Gomes et al. 2014), in some cases a reduced uptake of micronutrients by plants has been found (Eker et al. 2006; Tesfamariam et al. 2009; Cakmak et al. 2009). While in others (Duke et al. 2012; Duke et al 2018) no effect on micronutrient content was found. More research is required on whether glyphosate application leads to a reduced micronutrient content specifically in wildlife forage, and whether this is implicated in the population declines of moose in BC.

3.2 Soil and Water Quality

3.2.1 Glyphosate/AMPA fate in soils

After application, glyphosate is largely immobilized in the soil due to its strong sorption characteristics that allow it to bind with soil particles and organic materials. Once glyphosate reaches the soil, the main pathway for glyphosate dissipation in soil is microbial degradation, as many species of soil microorganisms can use glyphosate as their soil carbon source (Durkin, 2003). One of the main compounds released during the microbial breakdown process, ~~aminomethylphosphonic acid (~~AMPA~~)~~, is likewise adsorbed to soils and biodegraded, yet considered to be a mild phytotoxin (Reddy et al., 2004; Gomes et al, 2014) with relatively unknown long-term consequences on soil organisms and plants.

Formatted: Highlight

Commented [MOU31]: Acronym previously defined.

Sorption and degradation processes are highly dependent on microbial activity and soil composition (Székács and Darvas, 2012). The rate of sorption and degradation of both glyphosate and AMPA vary greatly in agricultural applications, with half-lives ranging between a few days to several months, and even up to a year (Székács and Darvas, 2012). While it has been argued that the short growing season in northern climates may restrict degradation, North American studies in forest applications have found that the time for 50% dissipation (DT50) in litter and soil is 8 to 19 days, and 5 to 40 days respectively (Newton et al, 1984; Newton et al, 1994; Thompson et al, 2000; Feng and Thompson, 1990; Hagner et al, 2019).

3.2.2 Soil micro-organisms

Soil organisms play a crucial role in nutrient cycling and maintaining ecosystem productivity. Research on the effect of glyphosate in micro-organisms in laboratory studies has been contradictory. Laboratory studies have found exposure to glyphosate formulations may either decrease (Druille et al. 2013; Zaller et al. 2014; Tanney and Hutchinson, 2010; Estok et al. 1989; Sanogo et al. 2000; Diaz et al. 2003) or rarely stimulate (Laatikainen and Heinonen-Tanski 2002; Diaz et al. 2003) proliferation of certain fungal species. Laboratory studies on cultured microorganisms are likely to overestimate toxicity effects (Estok et al. 1989), however. Field studies of the effect of glyphosate application on forest soil organisms and microbial processes are limited and their findings often contradictory. Some detrimental effects on fungal communities and nutrient cycling have been documented by Munson et al. (1993) and Vitousek et al. (1992). Similarly, annual applications of glyphosate over a ~~five~~ five-year period in an Ontario plantation have resulted in reduced microbial biomass, microbial carbon, soil organic carbon ratio, which indicates a reduced capacity of the ecosystem to maintain its nutrient reservoir (Ohtonen et al., 1992). In contrast, other field studies have found minimal or no effect on microbial processes or fungal community structures (Busse et al. 2001; Houston et al. 2002; Haney et al., 2002; Stratton and Steward, 1992; Chakravarty and Chatarpaul, 1990), while others have found a short-term increase in microbial activity caused by the breakdown of glyphosate and AMPA (Wardle and Parkinson 1990, Mijangos et al. 2009, Ratcliff et al. 2006, Haney et al. 2002). The extent of the variation in results suggests more research is needed in forest applications of glyphosate to better understand direct effects on microbial communities. Research should look at effects on individual species and the indirect impacts resulting from these changes in the ecosystem.

Formatted: Highlight

3.2.3 Glyphosate/AMPA fate in water

s.13

s.13

s.13

s.13

The main ways that glyphosate could end up in aquatic ecosystems are by drift onto non-target areas or by soil particle mobilization after a storm event in the hours following glyphosate application (Rolando 2017). These risks may be minimized in field operations using electronic guidance systems, low drift nozzles, and meteorological monitoring of wind speed, temperature and humidity (Thompson et al., 2012). In the field, studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken (Thompson et al. 2004, Feng and Thompson 1990; Gluns et al. 1989; Adams et al. 2007).

s.13

One study in boreal ponds found a half-life of up to 11 days (Goldsborough and Brown, 1993)

The primary mechanisms behind the rapid breakdown or reduction of glyphosate in the water column are adsorption into benthic or suspended sediments, microbial breakdown of glyphosate and its breakdown products, and downstream dilution. Glyphosate does persist longer in oligotrophic water bodies or those that are cold, deep and low in microbial activity. Residues have been detected in benthic sediments of these systems for up to 18 months after application (Feng et al., 1990; Newton et al., 1994; Newton et al., 1984)

3.3 Climate Change

The Intergovernmental Panel on Climate Change notes that "in the long-term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit" (Nabuurs et al., 2007). Vegetation management (including, but not limited to, glyphosate application) can affect carbon sequestration due to its impact on vegetation structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows the establishment of a woody crop delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools.

When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species. Mixedwood stands comprised of spruce and aspen are likely to have a higher yield than either pure spruce or pure aspen stands because of differences in shade tolerance, phenology, rooting patterns, and physical space occupied by different sized canopies (Gough et al. 2019, McCulloch and Kabzems 2009). Retaining between 1,000 and 10,000 stems/ha of aspen is expected to increase total stand production by approximately 20% relative to a pure spruce stand, but this will be at the expense of spruce volume (Kabzems et al. 2007). Harper and Roach (2014) similarly report that in a modeled mixedwood, the total stand volume is higher in a spruce-aspen mixedwood compared to pure spruce or pure aspen stands.

Formatted: Highlight

This effect varies with species, however. Growth and yield models in the SBS show that total stand volumes in lodegepole pine-aspen stands are not different from pure aspen or pure pine stands (Harper, 2015). In all cases, the increase of deciduous volume is at the expense of conifer volume (Kabzems et al 2007; Harper and Roach, 2014; Harper, 2015).

Forest soils are the largest carbon pool in boreal and temperate ecosystems, often storing greater amounts of carbon than living biomass and coarse woody debris (Heath et al, 2003). Laganiere et al (2017) found that aspen trees stored less carbon in the forest floor and similar amounts in the mineral soil relative to conifers. However, their study also showed that soil organic carbon stock under aspen is more stable, rendering it more protected against environmental changes and soil disturbances.

A source of uncertainty in determining the difference in carbon sequestration between mixedwoods and pure conifer stands stems from the shorter lifespan of deciduous trees compared to conifers, which ultimately affects the amount of time that a stand can act as a carbon sink (Harper and Roach, 2014).

3.4 Wildfire

Vegetation management (including, but not limited to, glyphosate application) has the potential of altering the amount of deciduous trees left on a site after regeneration. Deciduous stands often act as natural fire breaks. In summer months, deciduous stands moderate microclimates, inhibit wind movement, help maintain lower air temperature and higher humidity and maintain soil and surface fuel moisture longer into the fire season (Chesterman, 1997)s.13
s.13

The physical properties of aspen, in particular, resist intense fire behaviour (Alberta 2012), making it a popular choice for fuel treatments in the wildland urban interface throughout North America (Gray 2018, Shepperd et al. 2006). Usually, fire does not get carried into the crowns of deciduous stands due to the absence of ladder fuels. Consequently, fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires (Alexander and Lanoville, 2004). The FBP system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous[13] or leaf-on mixedwood stands. Amongst deciduous trees, poplars show the most fire resistance s.13
s.13

s.13

Table 5. Fire resistance of broadleaved species (BCMFLNRORD 2019).

Fire resistance/resilience	Broadleaved species
High	Balsam poplar, black cottonwood
High-Moderate	Gary oak, bigleaf maple
Moderate	Trembling aspen, red alder, paper birch
Low	Arbutus

3.5 First Nations

Some First Nations across BC have expressed concern over the use of glyphosate in forests. Some of these concerns relate to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated. Chief Ron Ignace (Skeetchestn Indian Band) has indicated that he considers the spraying of herbicide "an act of cultural genocide, because you are killing our foods and medicines."[14] The McLeod Lake Indian Band passed a Band Council resolution in July 2019 that reaffirms the Band's zero tolerance for herbicide, pesticide, insecticide and chemical fertilizer use within the traditional

Formatted: Highlight

Formatted: Highlight

[13] During spring months before leaf-out in deciduous stands, the grass has the potential to dry out rapidly in the absence of canopy cover, creating a higher surface fire potential until green-up and leaf-on occurs.

[14] https://acuriouslookatpoliticsinbc.blogspot.com/2019/09/adam-olsen-skeetchestn-indian-band.html?fbclid=IwAR3kXSjKGMzGu6V5qs4Gxvu9l06PdbVbL5TtjdfWvallemumCz0TiAsRnaQ

territory. The resolution indicates that glyphosate is deemed carcinogenic and has a direct impact on wildlife, ecosystems and water sources. Where there is doubt concerning the science about herbicides, there can be an inclination toward the precautionary principle.

Two-way education, communication, collaboration and joint problem solving between stakeholders is key to reaching agreements about land use. Traditional plant users should, for example, take into consideration that the presence of glyphosate does not indicate toxicity (Wood, 2019) or that plant diversity, richness and abundance is not generally not affected in the years following application. Similarly, forest managers need to acknowledge and communicate uncertainty regarding minor effects of glyphosate use. There is mounting evidence for example that Glyphosate/AMPA may persist in low levels in some perennial plants (Wood, 2019), and that it may also disrupt the creation of some plant secondary compounds, some of which may be the compounds responsible for medicinal effects in traditional medicines (Gomes et al. 2014).

s.13

s.13

- Designating no spray areas
- Prioritizing manual treatments
- Prioritizing backpack instead of aerial application
- Prioritizing spot spray around individual stems
- Increasing buffers
- Leaving untreated patches
- Providing alternative gathering sites
- Providing additional notification and signage
- Adjusting treatment schedules to avoid disrupting First Nation activities

3.6 Public Use

Forest managers are faced with mounting public pressure over the safety of glyphosate use (Thomson and Pitt, 2011). Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping or hiking. The Canada Pest Management Regulatory Agency's review on glyphosate (PMRA 2017) has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health. This applies to people that may come in contact to glyphosate from food or water, by handling the product or by entering treated sites.

There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues (including game species such as moose, deer and hare) (Lautenschlager, 1992; Legris and Couture, 1991; Newton et al, 1984). Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue (Wood, 2019). Where detected, glyphosate residue levels averaged 0.79 ppm (highest level detected was 4 ppm). From a food consumption perspective, 0.1 ppm is the maximum residue level (MRL) allowed for non-designated food in Canada, although this value ranges from 0.08 to 40 for specific foods.

s.13

Formatted: Highlight

s.13

4 IMPACTS ON TIMBER SUPPLY

Vegetation control, including but not limited to glyphosate application, is in some cases necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests. Vegetation management is one key tool to meet these objectives.

Glyphosate is used in this context because of its cost-effectiveness compared to manual vegetation control methods. Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked (NSR) area particularly problematic areas with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

In Canada, decisions to not use chemical herbicides have been taken in Quebec and Nova Scotia. In Quebec, a provincial ban of glyphosate use on Crown land took effect in 2001 after severe public pressure and a series of public consultations. Forest regeneration would focus on early planting of tall stock and intensive manual brushing. Since then, plantation establishment and tending costs in Quebec have frequently exceeded $5,000/ha due to planting large stock and as many as three manual brushing treatments (Labbé et al. 2014). Dampier et al. (2006) reported that cost per cubic metre of wood tripled when conifer release was performed by motor-manual methods rather than aerial application of herbicide.

s.13

Formatted: Highlight

An audit of plantations in Nova Scotia after a decision was made not to use herbicides yielded similar findings. Following a survey of untreated plantations, results showed 87% of conifer plantations were considered failures (with less than 60% stocking), and only 3% met free growing standards 6-8 years post-harvest (Nicholson, 2007).

In BC, meeting free growing stocking standards ensures that sustainable timber supply is achieved. In cases where aggressive competing vegetation cannot be overcome to the extent that is practicable in order to meet free growing requirements, licensees may request relief from reforestation obligations under FPPR sec 97.1. Increasing the challenge to meet reforestation obligations on a broad scale may increase the risk for reduced plantation performance with significant timber supply impacts, such as in the case of Quebec.

4.1 s.13

s.13

There are ongoing efforts to further develop standards that facilitate deciduous management in the context of overall forest management objectives. One example is the inclusion of fire stocking standards in the Wildland Urban Interface, including the establishment and management of deciduous species to reduce fire behaviour in areas near communities and infrastructure.[17] In another example, a Hardwood Management Strategy was developed in 2008 to facilitate management of red alder, bigleaf maple and birch in the Coast Region.[18] Wildlife stocking standards are also being developed and regional guidance is available.

15 http://www.fsjpilotproject.com/documents/SFMPappend2016/Appendix_6_Reforestation_Strategy_Stocking_Standards_and_Crop_Tree_Requirements.pdf

16 https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/stocking-standards

17 https://www.for.gov.bc.ca/hfp/silviculture/Fire%20Management%20Stocking%20Standards%20Guidance%20%20Document%20March%202016.pdf

18https://www.for.gov.bc.ca/rco/stewardship/CRIT/docs/Hardwood%20Management%20in%20the%20Coast%20Forest%20Region%20(final%20July11V2).pdf

s.13

5 RECOMMENDATIONS

s.13

19 https://www.bcfpb.ca/wp-content/uploads/2019/07/SR58-Tactical-Forest-Planning.pdf

20 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-strategies/2018_final_merritt_iss_tactical_plan_v11.pdf

s.13

6 CONCLUSIONS

Glyphosate is one of many vegetation management tools available to forest managers. It is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. Forest managers are faced with mounting public pressure over the perceived environmental impacts of forestry applications of glyphosate. In particular, concerns over the removal of broadleaf tree species from the landscape and the consequent impacts on risk of wildfire, wildlife habitat, climate change, etc. A review of current inventory data however shows that stands that have been treated with glyphosate retain 15-21% deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.

Field studies have also shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals s.13
songbirds and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.

s.13

6 REFERENCES

Adams, G.W., Smith, T., and Miller, J.D. 2007. The Absence of Glyphosate Residues in Wet Soil and the Adjacent Watercourse after a Forestry Application in New Brunswick, Northern Journal of Applied Forestry, Volume 24, Issue 3.

Alexander, M.E., and Laneville, R.A. 2004. The International Crown Fire Modelling Experiment fuel treatment trials [abstract]. Page 222 in R.T. Engstrom, K.E.M. Galley, and W.J. de Groot (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

Baker, L. F., Mudge, J. F., Houlahan, J. E., Thompson, D. G. and Kidd, K. A. 2014. The direct and indirect effects of a glyphosate-based herbicide and nutrients on Chironomidae (Diptera) emerging from small wetlands. Environmental Toxicology and Chemistry 33:2076-2085.

Baker, L. F., Mudge, J.F, Thompson, D.G, Houlahan, J.E and Kidd, K.E. 2016. The combined influence of two agricultural contaminants on natural communities of phytoplankton and zooplankton. Ecotoxicology 25:1021-1032.

BC Ministry of Forests, Lands and Natural Resource Operations. 2008. Tree species composition and diversity in British Columbia. FREP Report #14.

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development. 2018, Silviculture Surveys Procedures Manual Regen Delay, Stocking and Free Growing Surveys plus Alternative Survey Methodologies. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

Bell, F. W. and Newmaster, S.G. 2002. The effects of silvicultural disturbances on the diversity of seed-producing plants in the boreal mixedwood forest. Can J. For Res. Vol 32 (7), p 1180-1191. https://digitalcommons.usu.edu/aspen_bib/389

Biring, B.S. and Hays-Byl, W.J. 2000. Ten-year Conifer and Vegetation Responses to Glyphosate Treatment in the SBSdw3. BC Ministry of Forests Extension Note 46.

Biring, B.S., Hays-Byl, W.J. and Hoyles, S.E., 1999. *Twelve-year conifer and vegetation responses to discing and glyphosate treatments on a BWBSmw backlog site*. British Columbia, Ministry of Forests Research Program.

Biring, B.S.; Comeau, P.G.; Fielder, P. 2003. Long-term effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in Southern British Columbia. Annals of Forest Science 60(7):681-690.14.

Boateng J.O., Heineman, J.L., McClarnon, J. and Bedford, L. 2006.Twenty year responses of white spruce to mechanical site prepara-tion and early chemical release in the boreal region of northeastern British Columbia. Can. J. For. Res. 36: 2386–2399.

Bureau du forestier en chef. 2015. Succes des plantations. Avis du Forestier en chef. FEC-AVIS-04-2015, Roberval, Quebec, 22 p. +annexes. http://forestierenchef.gouv.qc.ca/wpcontent/uploads/2015/12/fec-avis-04-201S.pdf

Busse, M.D., Ratcliff, A.W., Stestak, C.J., Powers, R.F. 2001. Glyphosate toxicity and the effects of long-term vegetation control on soil microbial communities. Soil Biology & Biochemistry, Vol. 33: 1777-1789.

Cakmak, I., Yazici, A., Tutus, Y. and Ozturk, L., 2009. Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium, and iron in non-glyphosate resistant soybean. European Journal of Agronomy, 31(3), pp.114-119.

CCME (Canadian Council of Ministers of the Environment). 2012. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Glyphosate. In: Canadian environmental quality guidelines, Canadian Council of Ministers of the Environment, Winnipeg.

Chakravarty, P. and Chatarpaul, L., 1990. Non-target effect of herbicides: II. The influence of glyphosate on ectomycorrhizal symbiosis of red pine (Pinus resinosa) under greenhouse and field conditions. *Pesticide science*, *28*(3), pp.243-247.

Chesterman, D.A., 1997. Microclimate of aspen forests. University of Alberta M.Sc. thesis.

Cole, E., Youngblood, A. and Newton, M. 2003.Effects of competing vegetation on juvenile white spruce (Picea glauca(Moench)Voss) growth in Alaska. Ann. For. Sci. 60: 1–11

Comeau, P.G., Harper, G., Blache, M.E., Boateng, J.O. and Gilkeson, L., 1996. Integrated forest vegetation management: Options and applications.

Comeau, P.G., Biring, B.S. and Harper, G.J., 1999. Conifer response to brushing treatments: a summary of British Columbia data. Extension Note, British Columbia Ministry of Forests, (41), p.12.

Comeau, P.G., Biring, B.S., and Harper, G.J. 2000. Effectiveness of Repeated Manual Cutting and Glyphosate for Release of Engelmann Spruce from Mixed-Shrub Herb Vegetation. Western Journal of Applied Forestry 15(3):154-162. http://dx.doi.org/10.1093/wjaf/15.3.154

Comeau, P. and Fraser, E., 2018. Plant Community Diversity and Tree Growth Following Single and Repeated Glyphosate Herbicide Applications to a White Spruce Plantation. Forests, 9(3), p.107.

Comeau, P.G. and Harper, G.J., 2009. Effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia Year 15 results. The Forestry Chronicle, 85(4), pp.583-592.

Connor, J.F. and McMillan, L.M., 1990. *Winter utilization by moose of glyphosate-treated cutovers*. Ontario Ministry of Natural Resources, Northwestern Ontario Forest Technology Development Unit.

Custer, T.W., Cox, E., & Gray, B. 2004. Trace elements in moose (Alces alces) found dead in Northwestern Minnesota, USA. Science of the Total Environment, 330(1): 81-87.

Dampier, E.E., Bell, F.W., St-Amour, M., Pitt, D.G., Luckai, N.J. 2006. Cutting versus herbicides: Tenth-year volume and release cost-effectiveness of sub-boreal conifer plantations. Forestry Chronicle 82(4):521-528. https://pubs.cif-ifc.o rg/doi/10.5558/tfc82521-4

Diaz, G., Carrillo, C., and Honrubia, M. 2003. Differential responses of ectomycorrhizal fungi to pesticides in pure culture. Cryptogam.: Mycol. 24: 199–211.

Druille, M., Cabello, M.N., Omacini, M. and Golluscio, R.A., 2013. Glyphosate reduces spore viability and root colonization of arbuscular mycorrhizal fungi. *Applied Soil Ecology*, *64*, pp.99-103.

Duke, S.O., Lydon, J., Koskinen, W.C., Moorman, T.B., Chaney, R.L. and Hammerschmidt, R., 2012. Glyphosate effects on plant mineral nutrition, crop rhizosphere microbiota, and plant disease in glyphosate-resistant crops. Journal of agricultural and food chemistry, 60(42), pp.10375-10397.

Duke, S.O., Rimando, A.M., Reddy, K.N., Cizdziel, J.V., Bellaloui, N., Shaw, D.R., Williams, M.M. and Maul, J.E., 2018. Lack of transgene and glyphosate effects on yield, and mineral and amino acid content of glyphosate-resistant soybean. Pest management science, 74(5), pp.1166-1173.

Dunbar, J., McCulloch, L. and Kabzems, R., 2011. Bluejoint Stand Establishment Decision Aid. Journal of Ecosystems and Management, 11(3).

Durkin, PR. Glyphosate - Human health and ecological risk assessment report. Syracuse Environmental Research Associates Inc, Fayetteville NY 2003.

Edge, C. B., Gahl, M.K., Pauli, B.D, Thompson, D.G. and Houlahan, J.E. 2011. Exposure of juvenile green frogs (Lithobates clamitans) in littoral enclosures to a glyphosate-based herbicide. Ecotoxicology and environmental safety 74:1363-1369.

Edge, C. B., M. K. Gahl, D. G. Thompson, and J. E. Houlahan. 2013. Laboratory and field exposure oftwo species of juvenile amphibians to a glyphosate-based herbicide and Batrachochytrium dendrobatidis. Science of the Total Environment 444:145-152.

Edge, C. B., D. G. Thompson, C. Hao, and J. E. Houlahan. 2012. A silviculture application of the glyphosate-based herbicide VisionMAX to wetlands has limited direct effects on amphibian larvae. Environmental Toxicology and Chemistry 31:2375-2383.

Edge, C., M. Gahl, D. Thompson, C. Hao, and J. Houlahan. 2014a. Variation in amphibian response to two formulations of glyphosate-based herbicides. Environmental Toxicology and Chemistry 33:2628-2632.

Edge, C., D. Thompson, C. Hao, and J. Houlahan. 2014b. The response of amphibian larvae to exposure to a glyphosate-based herbicide (Roundup WeatherMax) and nutrient enrichment in an ecosystem experiment. Ecotoxicology and Environmental Safety 109:124-132.

Edginton, A.N., Sheridan, P.M., Stephenson, G.R., Thompson, D.G. and Boermans, H.J., 2004. Comparative effects of pH and Vision® herbicide on two life stages of four anuran amphibian species. *Environmental Toxicology and Chemistry: An International Journal*, *23*(4), pp.815-822.

Ehrentraut, G., and Brantner, K. 1990. Vegetation management by manual and mechanical means in Alberta boreal forests. For. Chron. 66: 366–368.

Eker, S., Ozturk, L., Yazici, A., Erenoglu, B., Romheld, V. and Cakmak, I., 2006. Foliar-applied glyphosate substantially reduced uptake and transport of iron and manganese in sunflower (Helianthus annuus L.) plants. Journal of agricultural and food chemistry, 54(26), pp.10019-10025.

Eremko, R.D. 1986. The effects of the aerial application of Roundup on water quality in the Nicoamen River watershed. Unpubl.report for B.C. Min. For. & Lands, Lillooet District.

Eschholz, W.E., Servello, F.A., Griffith, B., Raymond, K.S., and Krohn, W.B. 1996. Winter use of glyphosate-treated clearcuts by moose in Maine. J. Wildl. Manage.60: 764–769

Estok, D., Freedman, B., and Boyle, D. 1989. Effects of the herbicides 2,4-D, glyphosate, hexazinone, and triclopyr on the growth of three species of ectomycorrhizal fungi. Bull. Environ. Contam. Toxicol. 42(6): 835–839. doi:10.1007/BF01701623. PMID: 2743015.

Feng, J.C. and D.G. Thompson. 1990. Fate of glyphosate in a Canadian forest watershed. 2. Persistence in foliage and soils. J. Agric. Food. Chem. 38:

Feng, J.C., Thompson, D.G., Reynolds, P.E. 1990. Fate of glyphosate in a Canadian forest watershed. 1. Aquatic residues and off-target deposit assessment. J. Agric. Food Chem. 1990, 38, 1110-1118.

Flynn, A., Franzmann, A.W., Arneson, P.D. and Oldemeyer, J.L., 1977. Indications of copper deficiency in a subpopulation of Alaskan moose. The Journal of Nutrition, 107(7), pp.1182-1189.

Folmar, L.C., Sanders, H.O. & Julin, A.M. Arch. Environ. Contam. Toxicol. (1979) 8: 269. https://doi.org/10.1007/BF01056243

Frank, A., Galgan, V. and Petersson, L.R., 1994. Secondary copper deficiency, chromium deficiency and trace element imbalance in the moose (Alces alces L.): effect of anthropogenic activity. Ambio (Sweden).

Freedman, B., Morash, R., and MacKinnon, D. 1993. Short-term changes in vegetation after the silvicultural spraying of glyphosate herbicide onto regenerating clearcuts in Nova Scotia, Canada. Can. J. For. Res.23:230D-2311.

Frey, B.R., Lieffers, V.J., Landhäusser, S.M., Comeau, P.G. and Greenway, K.J., 2003. An analysis of sucker regeneration of trembling aspen. Canadian Journal of Forest Research, 33(7), pp.1169-1179.

Giesy J.P., Dobson S., Solomon K.R. (2000) Ecotoxicological Risk Assessment for Roundup® Herbicide. In: Ware G.W. (eds) Reviews of Environmental Contamination and Toxicology. Reviews of Environmental Contamination and Toxicology, vol 167. Springer, New York, NY

Gluns, D.R. 1989. Herbicide residue in surface water following an application of Roundup® in the Revelstoke Forest District. B.C. Ministry of Forests and Lands. RR 88001-NE.

Goldsborough, L.G. and Beck, A.E., 1989. Rapid dissipation of glyphosate in small forest ponds. *Archives of Environmental Contamination and Toxicology*, *18*(4), pp.537-544.

Goldsborough, L.G. and D.J. Brown. 1993. Dissipation of glyphosate and aminomethylphosphonic acid in water and sediments of boreal forest ponds. Environ. Toxicol. Chem. 12:1139-1147

Gomes, M.P., Smedbol, E., Chalifour, A., Hénault-Ethier, L., Labrecque, M., Lepage, L., Lucotte, M. and Juneau, P., 2014. Alteration of plant physiology by glyphosate and its by-product aminomethylphosphonic acid: an overview. *Journal of experimental botany*, *65*(17), pp.4691-4703.

Gough, C.M, J.W. Atkins, R.T. Fahey and B.S. Hardaman. 2019. High rates of primary production in structurally complex forests, Ecology {2019). DOI: 10.1002/ecy.2864

Gray, R.W. 2018. Trembling aspen stands as firebreaks: what options are available for stimulating aspen stand expansion. City of Cranbrook, UBCM Fuel Management Pilot Program. https://wfca.ca/wpcontent/ uploads/2018/06/Trembling-Aspen-Stands-as-Firebreaks FINAL-REPORT.pdf

Guynn DC, Guynn ST, Wigley TB, Miller DA. 2004. Herbicides and forest biodiversity: what do we know and where do we go from here? WIldlife Society Bulletin. 2004; 32(4):1085-92.

Haney, R.L., Senseman, S.A. and Hons, F.M., 2002. Effect of Roundup Ultra on microbial activity and biomass from selected soils. *Journal of Environmental Quality*, *31*(3), pp.730-735.

Hagner, M., J. Mikola, I. Saloniemi, K. Saikkonen, M. Helander. 2019. Finnish ecological sustainability study: Glyphosate-based Roundup herbicide has 'minor, transient' impacts on soil and animal health. Scientific Reports (9)1: 8540. doi.org/10.1038/s41598-019-44988-5

Harper, G.J. 2015. Lodgepole pine and trembling aspen mixedwoods: Growth and yield within 22 to 39 year old pine plantations of northern interior British Columbia. For. Chron. 91(5): 502-518. https://www.researchgate.net/publication/291424207_Lodgepole_pine_and_trembling_aspen_mixedwoods_Growth_and_yield_within_22_to_39_year_old_pine_plantations_of_northern_interior_British_Columbia

Harper, G. 2017. Lodgepole pine and trembling aspen competition: Neighbourhood studies within 22 to 39 year old pine plantations of northern British Columbia. Forestry Chronicle, 2017, 93{3): 226-240, https:// doi .org/10.5558/tfc2017 -031

Harper, G.; Roach, J. 2014. The role of broadleaf trees: impacts of managing boreal and sub-boreal mixedwood forests in British Columbia. Extension Note- British Columbia Ministry of Forests and Range 2014 No.110 pp.8 pp.

Harper, G.J., Biring, B.C. and Heineman, J. 1997. Mackay River Herbicide Trial: Conifer Response 9 Years Post-treatment. BC Ministry of Forest Research Branch. Research Report 11.

Harper, G.J., Comeau, P.G. and Biring, B. S. 2005. A comparison of herbicide and mulch mat treatments for reducing grass, herb, and shrub competition in the BC Interior Douglas-fir zone—

Ten-year results. Western Journal of Applied Forestry, Volume 20, Issue 3, July 2005, Pages 167–176.

Hart, D. and Comeau, P.G. 1992. Manual brushing for forest vegetation management in British Columbia: A review of current knowledge and information needs. B.C. Ministry of Forests, Forest Science Research Branch. Land Management Report Number 77.

Hawkins, C.D.B.; Dhar, A.; Lange, J. 2013. Vegetation management with glyphosate has little impact on understory species diversity or tree growth in a sub boreal spruce plantation—A case study. Plant Biosyst. 2013, 147, 105–114.

Health Canada Pesticide Management Regulatory Agency. 2017. Re-evaluation decision glyphosate RVD2017-01. https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/registration-decision/2017/glyphosate-rvd-2017-01.html

Health Canada Pesticide Management Regulatory Agency. 2019. Statement from Health Canada on glyphosate. https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

Heath, L.S., Kimble, J.M., Birdsey, R.A. and Lal, R., 2003. The potential of US forest soils to sequester carbon. *In: Kimble, JM; Heath, Linda S.; Birdsey, Richard A.; Lal, R., eds. The potential of US forest soils to sequester carbon and mitigate the greenhouse effect. Boca Raton: CRC Press: 385-394.*

Heineman, J.L., S.W. Simard, D.L. Sachs and W.J. Mather. 2005. Chemical, grazing, and manual cutting treatments in mixed herb-shrub communities have no effect on interior spruce survival or growth in southern interior British Columbia. Forest Ecology and Management. Vol *205, 1-3,* p 359-374. https:// doi .org/10.1016/j. foreco.2004.10.038

Hjeljord, O. and Gr⊘ nvold, S., 1988. Glyphosate application in forest—ecological aspects: VI. Browsing by moose (Alces alces) in relation to chemical and mechanical brush control. *Scandinavian Journal of Forest Research*, *3*(1-4), pp.115-121.

Houlahan, J.E., C.S. Findlay, B.R. Schmidt, AH Meyer and S.L. Kuzmin. 2000. Quantitative evidence for global amphibian population declines. Nature 404. 752-755.

Houston, A.P.C., Visser, S. and Lautenschlager, R.A., 2002. Response of microbial processes and fungal community structure to vegetation management in mixedwood forest soils. Canadian journal of botany, 76(12), pp.2002-2010.

Howe, C.M., Berrill, C.M., Pauli, B.D., Helbing, C.C., Werry, K. and Veldhoen, N. 2004. Toxicity of glyphosate-based pesticides to four North American frog species. Environmental Toxicology and Chemistry: No. 23, pp. 1928–1938.

Kabzems, R., A.L. Nemec, and C. Farnden. 2007. Growing trembling aspen and white spruce intimate mixtures: Early results (13-17 years) and future projections. BC Journal of Ecosystems and management 8(1):1-14. uri: http://www.forrex.org/publications/jem/ISS39/vol8 no1 artl.pdf

Kabzems R. and G.J. Harper. 2015. Conifer and vegetation responses to pre-planting applications of glyphosate and hexazinone on a boreal backlog site, Sx trial 82502g-2. Prov. B.C., Victoria, B.C. Tech. Rep. 087. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr087.htm

Kissane, Z. and Shephard, J.M., 2017. The rise of glyphosate and new opportunities for biosentinel early-warning studies. Conservation biology, 31(6), pp.1293-1300.

Kuzyk, G., Marshall, S., Procter, C., Schindler, H., Schwantje, H., Gillingham, M., Hodder, D., White, S. and Mumma, M., 2018. Determining factors affecting moose population change in British Columbia.

Laatikainen, T., and Heinonen-Tanski, H. 2002. Mycorrhizal growth in pure cultures in the presence of pesticides. Microbiol. Res. 157(2): 127–137. doi:10.1078/0944-5013-00139. PMID: 12002401.

Lautenschlager, RA. 1992. Effects of conifer release with herbicides on moose: browse production, habitat use, and residues in meat. Alces 28:215-222

Lautenschlager, R.A., Dalton, W.J., Cherry, M.L., and Graham, J.L. 1999. Conifer release alternatives increase aspen forage quality in northwestern Ontario. J. Wildl. Manage.63: 1320–1326.

Labbé, F., Lainesse, M., Nadeau, F-R., Prégent, G., Savary, A. 2014. Analyse de rentabilité économique des plantations d'épinette noire et blanche et de pin gris. Bureau de mise en marché des bois, Québec (Québec). https://www.bmmb.gouv.qc.ca/analyses-economiques/.

Laganiere, J.; Boca, A.; Van Miegroet, H.; Pare, D. 2017. A tree species effect on soil that is consistent across the species' range: the case of aspen and soil carbon in North America . Forests 8: 113.

Lanctot, C., L. Navarro-Martin, C. Robertson, B. Park, P. Jackman, B. D. Pauli, and V. L. Trudeau. 2014. Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frog (Litho bates sylvaticus) tadpoles. II: Agriculturally relevant exposures to Roundup WeatherMax® and Vision® under laboratory conditions. Aquatic Toxicology 154:291-303.

Lanctot, C., C. Robertson, L. Navarro-Martin, C. Edge, S. D. Melvin, J. Houlahan, and V. L. Trudeau. 2013. Effects of the glyphosate-based herbicide Roundup WeatherMax® on metamorphosis of wood frogs (Litho bates sylvaticus) in natural wetlands. Aquatic toxicology 140-141:48-57.

Lautenschager, R.A. 1993. Response of wildlife to forest herbicide applications in northern coniferous ecosystems. Can. J. For. Res. 23: 2286-2299

Lautenschlager, R.A., and Sullivan, T.P. 2002. Effects of herbicide treatments on biotic components inregenerating northern forests. For. Chron.78: 1–37.

Legris, J.; Couture, G. Residus de Glyphosate dans le Gibier (Lievre, Orignal Qt cerf de Virginie) Suite a des Pulverisations en Milieu Forestier en 1988; Quebec Ministere des Forest, Direction de I' evaluation Environnementale: Charlesbourg, QC, Canada, 1991.

Lindgren, P.M.F., and T.P. Sullivan. 2001.1nfluence of alternative vegetation management treatments on conifer plantation attributes: abundance, species diversity, and structural diversity. For. Ecol. Manag. 142(1-3): 163-182

Macadam, A. and Kabzems, R. 2006. Vegetation Management Improves Early Growth of White Spruce More Than Mechanical Site Preparation Treatments, Northern Journal of Applied Forestry, Volume 23, Issue 1, March 2006, Pages 35–46, https://doi.org/10.1093/njaf/23.1.35

McCulloch, L. and R. Kabzems. 2009. British Columbia's northeastern forests: Aspen Complex Stand Establishment Decision Aid. BC Journal of Ecosystems and Management 10(2):51-58. www.forrex.org/publications/jem/ISS51/vol10 no2 art5.pdf

Meidinger and Pojar, 1991. Ecosystems of British Columbia. Special report Series 6, BC Ministry of Forests.

Mertens, M., Höss, S., Neumann, G., Afzal, J. and Reichenbecher, W., 2018. Glyphosate, a chelating agent—relevant for ecological risk assessment. Environmental Science and Pollution Research, 25(6), pp.5298-5317.

Mesnage, R., Defarge, N., De Vendômois, J.S. and Seralini, G.E., 2015. Potential toxic effects of glyphosate and its commercial formulations below regulatory limits. Food and Chemical Toxicology, 84, pp.133-153.

Mijangos, I., Becerril, J.M., Albizu, I., Epelde, L. and Garbisu, C., 2009. Effects of glyphosate on rhizosphere soil microbial communities under two different plant compositions by cultivation-dependent and-independent methodologies. *Soil Biology and Biochemistry*, *41*(3), pp.505-513.

Miller, D.T. 1985. Conifer release in the inland northwest - Effects p. 17-24 in weed control for forest productivity in the interior west. Symp Proce Spokane. WA February 5-7, 1985. Washington State University

Morgan, M.J., and J.W. Kiceniuk. 1992. Response of Rainbow trout to a two month exposure to Vision(!), a glyphosate herbicide. Bull. Environ. Contam. Toxicol. 48:772-780

Munson, A.D., Margolis, H.A. and Brand, D.G., 1993. Intensive silvicultural treatment: impacts on soil fertility and planted conifer response. *Soil Science Society of America Journal*, *57*(1), pp.246-255.

Nabuurs, J., Masera, 0., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., Elsiddig, E., FordRobertson, J., Frumhoff, P., Karjalainen, T., Krankina, 0., Kurz, W., Matsumoto, M., Oyhantcabal, W., Ravindranath, N., Sanz, M. Sanchez, T. and Zhang, X. 2007: Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group Ill to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. *Dave,* L.A. Meyer {eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NV, USA.

Navarro-Martin, L., C. Lanctot, P. Jackman, B. J. Park, K. Doe, B. D. Pauli, and V. L. Trudeau. 2014. Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frogs (*Litho bates sylvaticus*) tadpoles. 1: Chronic laboratory exposures to Vision Max®. Aquatic Toxicology 154:278-290.

Navratil, S., K. Branter and J. Zasada. 1991.Regeneration in the mixedwoods. InA. Shortreid (ed.). Proc. of the Symposium onNorthern Mixedwoods '89. Sept. 12-14, 1989, Fort St. John, BC.FRDA Report 164, Forestry Canada, Pacific Forestry Centre. pp.32–48.

Newsome, T.A. and J.L. Heineman. 2016. Adjusting free-growing guidance regarding aspen retention in the Cariboo-Chilcotin: research to operational implementation. Prov. B.C., Victoria, B.C. Tech Rep 102. https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/TR102.htm

Newton, M., Cole, E.C., Lautenschlager, R.A., White, D.E., and McCormack, M.L., Jr. 1989. Browse availability after conifer release in Maine's spruce-fir forests. J. Wildl. Manage.53: 643–649.

Newton, M,; Howard, K.M.; Kelpsas, B.R.; Danhaus, R.; Lottman, C.M.; Dubelman, S. 1984. Fate of glyphosate in an Oregon forest. Journal of Agricultural and Food Chemistry 32:1144-1151

Newton M, Howard KM, Kelpsas BR, Danhaus R, Lottman CM, Dubelman S. 1984. Fate of glyphosate in an Oregon forest. Journal of Agricultural and Food Chemistry. 1984; 32:1144-51

Newton M, Horner LM, Cowell JE, White DE, Cole EC. Dissipation of glyphosate and aminomethylphosphonic acid in North American forests. Journal of Agricultural and Food Chemistry. 1994; 42(8):1795-802

Nicholson, J. 2007. Survey of plantations established between 1998-2000 (6-8 years of age) on eastern Crown land without herbicides.: Nova Scotia Department of Natural Resources, Forest Management Planning, Forest Research Report 83, 27 p

O'Hara, T.M., Carroll, G., Barboza, P., Mueller, K., Blake, J., Woshner, V. and Willetto, C., 2001. Mineral and heavy metal status as related to a mortality event and poor recruitment in a moose population in Alaska. Journal of Wildlife Diseases, 37(3), pp.509-522.

Ohtonen, R., Munson, A. and Brand, D., 1992. Soil microbial community response to silvicultural intervention in coniferous plantation ecosystems. *Ecological Applications*, *2*(4), pp.363-375

Perala, D.A., 1985. Using glyphosate herbicide in converting aspen to conifers. Research Paper, North Central Forest Experiment Station, USDA Forest Service, (NC-259).

Pesticide Management Regulatory Agency, 2015. Glyphosate revaluation decision RVD2015-1. Health Canada.

Pesticide Management Regulatory Agency, 2017. Glyphosate revaluation decision RVD2017-1. Health Canada.

Pitt, D.G. and Bell, F.W., 2005. Juvenile response to conifer release alternatives on aspen-white spruce boreal mixedwood sites. Part I: Stand structure and composition. The Forestry Chronicle, 81(4), pp.538-547.

Pitt, D.G., R.G. Wagner and W.D. Towill. 2004a.Ten years of veg-etation succession following ground-applied release treatments in young black spruce plantations. North. J. Appl. For. 21(3): 123–134

Pitt, D.G., Mihajlovich, M. and Proudfoot, L.M., 2004b. Juvenile stand responses and potential outcomes of conifer release efforts on Alberta's spruce aspen mixedwood sites. The Forestry Chronicle, 80(5), pp.583-597.

Raymond, K.S., Servello, F.A., Griffith, B., and Eschholz, W.E. 1996. Winter foraging ecology of moose onglyphosate-treated clearcuts in Maine. J. Wildl. Manage.60: 753–763

Ratcliff, A.W., Busse, M.D. and Shestak, C.J., 2006. Changes in microbial community structure following herbicide (glyphosate) additions to forest soils. *Applied Soil Ecology*, *34*(2-3), pp.114-124.

Reddy, K.N., Rimando, A.M., Duke, S.O. 2004. Aminomethylphosphonic acid, a metabolite of glyphosate, causes injury in glyphosate-treated, glyphosate-resistant soybean. Journal of Agricultural and Food Chemistry 52, 5139–5143

Reynolds, P .E., Scrivener, J.C., Holtby, LB. and Kingsbury, P.D., 1993. Review and synthesis of Carnation Creek herbicide research. The Forestry Chronicle, 69(3), pp.32.3-330.

Rolando, C.A.; Baillie, B.R.; Thompson, D.G.; Little, K.M . 2017. The risks associated with glyphosate-based herbicide use in planted forests. Forests 8(6): 208-233. https://www.mdpi.com/1999-4907/8/6/208

Rzymski, P., Klimaszyk, P., Kubacki, T. and Poniedziałek, B. 2013. The effect of glyphosate-based herbicide on aquatic organisms – a case study. Limnological Review. 13(4):215-220

Sanogo, S., Yang , X.B., and Scherm, H. 2000. Effects of herbicides on Fusarium solanif. sp. glycines and development of sudden death syndrome in glyphosate-tolerant soybean. Phytopathology, 90(1): 57–66. doi:10.1094/PHYTO.2000.90.1.57.PMID:18944572.

Santillo, D.J., Leslie, D.M., Jr., and Brown, P.W. 1989a. Responses of small mammals and habitat to glyphosate application on clearcuts. J. Wild. Manage. 53: 164-172.

Shepperd, Wayne D.; Rogers, Paul C.; Burton, David; Bartos, Dale L. 2006. Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada. Gen. Tech. Rep. RMRS-GTR-178. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station 122 p.

Simard, S. 2001. Effects of Operational Brushing on Conifers and Plant Communities in the Southern Interior of British Columbia: Results from PROBE 1991-2000, PRotocol for Operational Brushing https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh48.pdf

Simard, S. and A. Vyse. 2006 Trade-offs between competition and facilitation: a case study of vegetation management in the interior cedar-hemlock forests of southern British Columbia. Canadian Journal of Forest Research, 2006, 36(10): 2486-2496, https://doi.org/10.1139/x06-150

Simard, S. and A. Vyse. 2006 Trade-offs between competition and facilitation: a case study of vegetation management in the interior cedar-hemlock forests of southern British Columbia. Canadian Journal of Forest Research, 2006, 36(10): 2486-2496, https://doi.org/10.1139/x06-150

Sullivan, T.P. and D.S. Sullivan. 2003. Vegetation management and ecosystem disturbance impact of glyphosate herbicide on plant and animal diversity in terrestrial ecosystems. Environ. Rev. 2013: 11:37-59.

Sullivan TP, Sullivan OS. Vegetation management and ecosystem disturbance: impact of glyphosate herbicide on plant and animal diversity in terrestrial systems. Environmental Review. 2003; 11:37-59.

Székács, A. & Darvas, B., 2012. Forty years with glyphosate. in Herbicides - Properties, Synthesis and Control of Weeds, M. N. A. E.-G. Hasaneen, Ed., InTech, Rijeka, Croatia, 2012.

Tanney, J. B., & Hutchison, L. J. 2010. The effects of glyphosate on the in vitro linear growth of selected microfungi from a boreal forest soil. Canadian journal of microbiology, 56(2), 138-144.

Taylor, S.W., R.G. Pike and M.E. Alexander. 1996. Field guide to the Canadian forest fire behaviour prediction (FPB) system. FRDA Handbook 012. https://www.for.gov.bc.ca/hfd/pubs/Docs/Frh/Frh012.pdf

Tarazona, Jose V.; Court-Marques, Daniele; Tiramani, Manuela; Reich, Hermine; Pfeil, Rudolf; lstace, Frederique;Crivellente, Federica (April3, 2017). "Giyphosate toxicity and carcinogenicity: a review of the scientific basis of the European Union assessment and its differences with IARC". Archives of Toxicology. 91 (8): 2723-2743.

Tesfamariam, T., Bott, S., Cakmak, I., Römheld, V. and Neumann, G., 2009. Glyphosate in the rhizosphere—Role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants. European journal of agronomy, 31(3), pp.126-132.

Thiffault, N. & Roy, V. 2011. Living without herbicides in Québec (Canada): historical context, current strategy, research and challenges in forest vegetation management. Eur J Forest Res (2011) 130: 117. https://rd.springer.com/article/10.1007/s10342-010-0373-

Thompson, D.G. and Pitt, D.G., 2011. Frequently asked questions (FAQs) on the use of herbicides in Canadian Forestry. *forest*, *13*, p.14.

Thompson DG, Pitt DG, Buscarini TM, Staznik B, Thomas DR. 2000. Comparative fate of glyphosate and triclopyr herbicides in the forest floor and mineral soil of an Acadian forest regeneration site. Canadian Journal of Forest Research. 30:1808-16.

Thompson DG, Pitt DG, Staznik B, Payne NJ, Jaipersaid D, Lautenschlager RA, et al. 1997. On-target deposit and verticle distribution of aerially released herbicides. For. Chron. 73(1):47-59.

Thompson, D.G, Wojtaszek, B.F., Staznik, B., Chartband, D.T., Stephenson, R. 2004. Chemical and biomonitoring to assess potential acute effects of VisonR herbicide on native amphibian larvae in forest wetlands. Environ Toxicol Chem 2004;23:843– 9.

Thompson, D., Leach, J., Noel, M., Odsen, Sand Mihajlovich, M. 2012. Aerial forest herbicide application: comparative assessment of risk mitigation strategies in Canada. For. Chron. 88(2) 176-184.

Wan, M.T., Watts, R.G. & Moul, D.J. 1989. Effects of different dilution water types on the acute toxicity to juvenile pacific salmonids and rainbow trout of glyphosate and its formulated products. Bull. Environ. Contam. Toxicol. (1989) 43: 378. https://doi.org/10.1007/BF01701872

Wardle, D.A. and Parkinson, D., 1990. Influence of the herbicide glyphosate on soil microbial community structure. Plant and Soil, 122(1), pp.29-37.

Whitehead, R.J and Harper, G.J. 1998. A comparison of four treatments for weeding Engelmann spruce plantations in the Interior Cedar Hemlock Zone of British Columbia: ten years after treatment. Canadian Forest Service Information report (Pacific Forestry Centre); BC-X-379

Wood, J.E. and F.W. von Althen. 1993. Establishment of whitespruce and black spruce in boreal Ontario: Effects of chemical site preparation and post-planting weed control. For. Chron. 69:554–560.

Wood, J.L. 2019. The presence of glyphosate in forest plants with different life strategies one year after application. Canadian Journal of Forest Research, 2019, 49(6): 586-594, https://doi.org/10.1139/cjfr-2018-0331

Zaller, J.G., Heigl, F., Ruess, L. and Grabmaier, A., 2014. Glyphosate herbicide affects below ground interactions between earthworms and symbiotic mycorrhizal fungi in a model ecosystem. Scientific reports, 4, p.5634.

APPENDIX 1. INTERNATIONAL ASSESSMENTS

Various international expert panels and regulators have reviewed glyphosate and its effect on human health. The consensus among national pesticide regulatory agencies and scientific organizations is that labeled uses of glyphosate have demonstrated no evidence of human carcinogenicity (Tarazona et al., 2017).

IARC

In March 2015, the World Health Organization's (WHO) International Agency for Research on Cancer (IARC), consisting of 17 experts from 11 countries, classified glyphosate as "probably carcinogenic in humans" based on epidemiological studies, animal studies, and in vitro studies[21]. This was based on "limited" evidence of cancer in humans (from real-world exposures that actually occurred) and "sufficient" evidence of cancer in experimental animals (from studies of "pure" glyphosate). "Limited" evidence means that a positive association has been observed between exposure to the agent and cancer but that other explanations for the observations (called chance, bias, or confounding) could not be ruled out.

IARC also concluded that there was "strong" evidence for genotoxicity, both for "pure" glyphosate and for glyphosate formulations[22].

EFSA

The European Food Safety Authority (EFSA) of the European Union (EU) concluded in Oct. 2015 that "the substance is unlikely to be genotoxic (i.e. damaging to DNA) or to pose a carcinogenic threat to humans"[23].

Glyphosate was not proposed to be classified as carcinogenic under the EU regulation for classification, labelling and packaging of chemical substances. In particular, all the Member State experts but one agreed that neither the epidemiological data (i.e. on humans) nor the evidence from animal studies demonstrated causality between exposure to glyphosate and the development of cancer in humans. A supplementary document clarified that while carcinogenic glyphosate-containing formulations may exist, studies "that look solely at the active substance glyphosate do not show this effect[24].

21 https://www.iarc.fr/featured-news/media-centre-iarc-news-glyphosate/

22 https://monographs.iarc.fr/wp-content/uploads/2018/06/mono112-10.pdf

23 http://www.efsa.europa.eu/en/efsajournal/pub/4302

24 http://www.efsa.europa.eu/sites/default/files/4302_glyphosate_complementary.pdf

Joint FAO/WHO

The WHO and FAO Joint committee on pesticide residues issued a report in 2016 stating the use of glyphosate formulations does not necessarily constitute a health risk and giving admissible daily maximum intake limits (one milligram/kg of body weight per day) for chronic toxicity[25].

EPA

In 2017, the American Environmental Protection Agency (EPA) classified glyphosate as "not likely to be carcinogenic to humans"[26]. The Agency's assessment found no other meaningful risks to human health when the product is used according to the pesticide label.

ECHA

In March 2017, the Committee for Risk Assessment of European Chemicals Agency (ECHA) concluded that the available scientific evidence did not meet the criteria to classify glyphosate as a carcinogen, as a mutagen or as toxic for reproduction. However, it was classified as causing serious eye damage and toxic to aquatic life with long lasting effects[27].

APVMA

In 2017 the Australian Pesticides and Veterinary Medicines Authority (APVMA) reviewed the IARC monograms and other international assessments and concluded that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans[28]. APVMA provides a good on-line overview of various studies and issues as well as an explanation of the IARC assessment[29].

California

Agreeing with the IARC classification, California listed glyphosate as a known carcinogen on July 7, 2017, under Proposition 65 law, which would require indicating this carcinogenicity hazard on the product label of glyphosate-based herbicide products. However, in response to a legal claim by an agricultural coalition including the National Association of Wheat Growers, Monsanto Corporation and farmer groups, the U.S. District Court issued a preliminary injunction against this evaluation on the basis that the classification by IARC claims glyphosate only probably carcinogenic, while apparently all other regulatory and governmental bodies found the opposite, including the US EPA[30].

Canada

In 2015 Health Canada's Pest Management Regulatory Agency (PMRA) released a Proposed Re-evaluation Decision document on glyphosate[31]. This consultation document described the registration process for the use of herbicides in Canada and summary of the science evaluated

25 https://www.who.int/foodsafety/areas_work/chemical-risks/JMPR_2016_Report_May.pdf

26 https://www.epa.gov/pesticides/epa-releases-draft-risk-assessments-glyphosate

27 https://echa.europa.eu/-/glyphosate-not-classified-as-a-carcinogen-by-echa

28 https://apvma.gov.au/sites/default/files/publication/26561-glyphosate-final-regulatory-position-report-final_0.pdf

29 https://apvma.gov.au/node/13891

30 https://www.frontiersin.org/articles/10.3389/fenvs.2018.00078/full

31 http://publications.gc.ca/collections/collection_2015/sc-hc/H113-27-2015-1-eng.pdf

and the reasons for the proposed re-valuation decision. Input comments were solicited. Registered pesticides are re-evaluated by PMRA on a cyclical basis to ensure they meet modern health and environment safety standards and continue to have value. In April, 2017, Health Canada reapproved glyphosate. The Re-evaluation Decision document[32] summarizes the agency's final decision on glyphosate, the reasons for it and PMRA's response to comments received. An evaluation of the available scientific information found that products containing glyphosate do not present risks of concern to human health or the environment when used according to the revised label directions. As a requirement for the continued registration of glyphosate uses, new risk reduction measures were required for the end-use products registered in Canada. These included a restricted-entry period of 12 hours for agricultural uses, directions to apply when potential for drift into areas of human activity is minimised, environmental hazard statements, spray buffer zones, precautionary statements and use restrictions to reduce runoff to aquatic areas.

Following Canada Health's re-evaluation decision of 2017, eight notices of objection were received. There were also public concerns about the validity of the science as indicated in the so called 'Monsanto Papers'. On January 11, 2019, Health Canada issued a statement indicating that after a thorough scientific review, objections to glyphosate use could not be scientifically supported when considering the entire body of relevant data[33].

32http://publications.gc.ca/collections/collection_2017/sc-hc/H113-28/H113-28-2017-1-eng.pdf

33 https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

APPENDIX 2. STOCKING STANDARDS AND SURVEY CHANGES RELATED TO DECIDUOUS MANAGEMENT IN BC

2007: Recognizing the autecology of the competition species, specifically shrub and herb compared to broadleaf species (deciduous), and the effects of these specific competitors on managed coniferous stands;

2007: Using improved free growing decision-making tools, via the quadrant method to evaluate free growing and 'potentially' free growing trees at the plot level, considering:

• site series specific competition thresholds;

• competition thresholds specific to the silvics of managed crop species.

This is a more refined evaluation method in the Coast, North and South Areas, when compared to simply evaluating competition within a 1 m cylinder with standard crop to brush ratios, as used in the past.

2009: Employing regionally developed brush competition assessments, specific to many BEC variants in the three Cariboo Timber Supply Areas (TSAs) based on empirical data collected by silviculture researchers. This neighbourhood concept has led to a greater flexibility in crop trees being assessed as free growing when intermixed and overtopped by broadleaf competition. As well, certain BEC variants in the Cariboo consider broad leaf competition as 'non-deleterious', thus not affecting their status as free growing;

2011: Developing new Broadleaf Forest Health Free Growing Damage Criteria, used to assess the acceptability of broadleaves as free growing, given these deciduous species are specified as crop trees in an approved Forest Stewardship Plan;

2018: Expanding the 'non-deleterious' definition of broadleaf competition, in conifer managed stands, to all site series within the IDFdk4 and SBPSxc BEC variants within the three Cariboo TSAs.

APPENDIX 3. INTEGRATED PEST MANAGEMENT PRINCIPLES

Elements of Integrated Vegetation Management include:

1. Prevention

2. Pest Identification

3. Seedling and Vegetation Monitoring

4. Injury Thresholds and Treatment Decisions

5. Treatment Options and Selection Criteria

6. Post-Treatment Effectiveness Evaluation

Prevention

Prevention of vegetation competition issues can be done through:

- **Site preparation:** The intent of site preparation is to reduce the impacts of growth limiting factors that might inhibit seedling establishment or growth potential.
- **Planting:** Stock with high genetic worth can improve survival performance of planted seedlings. Similarly, large seedling stock that is tall with good diameter is better suited to compete for light and can withstand higher brush hazards.
- **Species selection:** Species selection is made based on the ecological suitability of a species to the specific site conditions on an area. Additional considerations include immediate and long-term forest health factors, future forest products, volume and value, climate change, and consistency with the Timber Supply Analysis.
- **Regeneration delay:** Seedlings that are quickly established are more likely to compete successfully with problematic vegetation. Especially on brush prone sites, seedlings should be planted as soon as possible following harvesting.
- **Microsite selection:** Seedlings that are planted in the best microsite possible and that remain undamaged during the planting process are more likely to compete successfully with problematic vegetation.
- **Fertilization:** Fertilization treatments can potentially improve seedling establishment and reduce the need for brushing.
- **Advanced regeneration**: Another stand establishment option is to utilize advanced growth in the understory at the time of harvest. This could involve partial cuts such as shelterwood silviculture systems where silvics and site conditions are appropriate.

Pest identification

In the context of vegetation management, the term "pest" refers to herbaceous, shrub and broadleaf complexes or communities that:

- Inhibit plantation establishment;
- Hinder optimal growth and development of crop trees;

- Prevent a stand from achieving free growing;
- Affect an established plantation's overall health; or,
- When combined with snow, causes damage to crop trees by snow press.

Identification of potential vegetation problems starts with sound ecosystem classification from which vegetation complexes can be predicted. Post-harvest assessments and seedling monitoring can also help in identifying potential or realized brush problems.

Seedling and vegetation monitoring

Surveys and walkthroughs are scheduled throughout the plantations' development in order to ensure that stocking and brush levels are acceptable and that free growing parameters will be achieved within the appropriate time frame. Monitoring includes post-harvest assessments, regeneration delay surveys, regeneration performance walkthroughs, and free growing surveys.

Injury Thresholds and Treatment Decisions

Decisions to control vegetation on a site may be based on a number of different protocols depending on regional and ecological parameters. Measures such as competition index (CI) and height to diameter ratio (HDR) may be used to determine whether competing vegetation is negatively impacting crop trees. Crop tree status and vigour may also be evaluated based on local knowledge or % of crop trees that are overtopped, threatened, or above the brush.

Competition Index (CI) is a simple index that measures the competition for sunlight with regards to crop trees. CI is calculated as the sum of the products of cover and height for all non-crop species within a 1.26 meter radius around a crop tree, divided by crop-seedling height. CI shows that growth declines with increases in competition index. There is a very rapid decline in growth as CI increases from 0 to 100. At CI=100, growth is approximately 60% of that of a seedling growing free from competition. At a CI=150, seedlings receive 30% of the full sunlight in midsummer and would achieve approximately 45% of potential growth rates (Comeau et al, 1993). Treatment may be recommended when CI>80.

Height to diameter ratio (HDR) of crop trees can indicate sturdiness. In low light conditions, conifers will put more resources toward height growth, making them susceptible to vegetation and snow press. Treatment may be recommended with HDR>40 or 50, depending on species, where >50% of stems exceed the HDR.

Vegetation Management Options and Selection Criteria

Aerial Application

Broadcast treatment with a helicopter equipped with low-pressure boom and high-volume nozzles. Variable application rates are possible. May control brush for 2-4 years.

Discretionary, non-continuous application across portions of the block can also be applied.

The most cost-effective treatment and the safest option for workers on the ground

Benefits	Limitations
• Effective control for a number of years	• Less selective than other methods

- Minimal contact of chemical to workers
- Low cost
- Can treat remote, steep, slashy ground more safely than alternatives
- Can treat large areas in short time

- Stringent application constraints
- Intensive prep and follow up
- High public profile
- Residual leave trees are obstacles
- Visual quality affected for years
- Technically demanding
- Drift can occur outside treatment areas

Backpack Application

Backpack broadcast - continuous application across treatment unit with low-pressure backpack sprayer with adjustable nozzles. Variable application rates are possible. May control brush for 2-4 years. Discretionary non-continuous, or spot treatment can be applied.

Benefits

- Effective control for a number of years
- Can treat blocks with standing residuals
- Selective. Can apply with precision
- Only small buffers needed on Pesticide Free Zones

Limitations

- Stringent application constraints
- Intensive prep and follow up
- Requires high level of supervision
- Exposure of workers to herbicide
- Safety concerns wearing heavy equipment on rough terrain
- Access and water availability
- Constrained by brush height
- Inconsistent results from dew, rainfall and missed spots that are difficult to detect during monitoring.
- Safety concerns evacuating from remote sites
- Crew availability

Cut Stump

Selective application of herbicide onto a cut stump of target vegetation. Brush saw or power saw cuts stump and a worker applies herbicide using a backpack sprayer, squeeze bottle or nozzle mounted on the saw. May control brush for about 4 years.

Benefits

- Effective control for a number of years,
- Longer treatment window
- Little herbicide exposure to workers
- Only small buffers needed on Pesticide Free Zones
- Low application rate

Limitations

- Stringent application constraints prevents resprouting (lowest limb)
- Intensive prep and follow up
- Requires high level of supervision
- Exposure of workers to herbicide
- Safety hazards operating powersaws
- Safety concerns wearing heavy equipment on rough terrain

Motor Manual

Workers cut target vegetation with powersaws or brush saws. May control herbaceous brush for less

than a year, deciduous brush for about 2 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatment
• Public acceptance	• Safety hazards operating powersaws
• Can be applied selectively	• Expensive treatment cost
• Can be used in PFZ buffers	• Relative short window for treatment
• Not effective on herbaceous	• Limited availability of workers
	• Slash loads can be fire hazards, limit trafficability

Hand Tools

Workers treat spots around crop trees with handheld cutters.

Girdling hardwoods to remove a continuous strip bark around circumference which kills trees 2-3 years later.

Snap/hinge- partially breaking smaller stems by hand.

May control brush for less than a year. Girdling can control brush for about 3 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatment
• Public acceptance	• Expensive treatment cost
• Can be applied selectively	• Repetitive strain injuries are common
• Can be used in PFZ buffers	• Limited availability of workers
s.13	• Girdling not effective on herbaceous

Sheep Grazing

Shepherds guide a flock of sheep (1,000-1,500} through treatment areas where they eat target

vegetation. May control brush for a year.

Benefits	Limitations
• No herbicide use	• Expensive treatment cost
• Not constrained by weather	• Some crop tree damage
• Safe for workers	• Herbaceous, limited height
	• Need good access, gentle terrain, low slash, blocks in proximity
	• Risk of disease to wildlife

• Risk from predators

Mechanical Site Preparation

Mechanically creating favourable planting spots that mitigate limiting site factors such as cold, poorly

aerated soils, competing vegetation and frost risk. Where brush hazards are high, mounding is preferred so seedlings are elevated, receive more light and vegetation falls away from crop trees rather than pressing over them. Mounding is done with excavators or implements attached to prime movers such as skidders. May control brush for 3-5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Public acceptance	• Access and soil disturbance
• Increased soil temperature	• Site constraints- trafficability
• Facilitates planting	• Availability of contractors in the north

Prescribed Burning

Prescribed burning is another form of site preparation using ground crews or a helicopter to apply a

controlled burn. May control brush for 3-5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Good seedbed, plantable spots	• Liability and risk of escape
	• Smoke and health effects
	• Risks to workers

Treatment Selection

Treatment methods for a specific site will be selected based on a number of factors including safety concerns, timing, treatment efficacy, cost, biophysical constraints, legal constraints, political constraints and concerns from other users and stakeholders. Some of these factors include:

- **Target species height**: Backpack treatments cannot be sprayed overhead. Sheep are also constrained by their ability to reach foliage and are restricted to sites with vegetation of <1m in height.
- **Target species diameter**: Girdling becomes impractical at diameters of less than 3 cm or greater than 10 cm.
- **Target species distribution**: Broadcast foliar treatments are not effective if target species are in clumps. Discretionary treatments are less appropriate if the target brush is evenly distributed.

- **Physical impediments to treatment**: Aerial treatments can be limited by residual trees, or small, irregular shaped treatment units. Ground-based treatments can be affected by steep slopes, uneven terrain, slash loading, difficult access and remote access.
- **Buffers**: Blocks with many features that require No Treatment Zones and Pesticide Free Zones (PFZs), such as water bodies, wetlands, roads, etc, may have little treatable area for herbicide treatments once all the buffers are established.
- **Timing**: Chemical treatment windows are small and require conifers hardening off to avoid chemical damage while target species are still succulent. Motor manual treatment windows may overlap with fire season and are dependent on fire risk safety measures.
- **Special wildlife features**: Heavy browsing might reduce the need for brushing if there is little alternative browse available. Treatments that create heavy slash loads that restrict game movement may be avoided. Sheep grazing may be a poor choice in high grizzly bear use areas.
- **Vulnerable plant species**: Vulnerable plant species are defined as those plants whose numbers are either limited or are important for browse or forage. Vulnerable plant species must be protected from broadcast treatments where identified.
- **First Nations rights infringement**: When specific information indicates that there is a higher likelihood of treatments infringing on First Nations rights on a unit, certain treatments may be considered unsuitable, or modified. For example, if consultation with a First Nation produced indicated that a specific site is used for berry-picking, a broadcast chemical treatment would be considered inappropriate.
- **Potential for conflict**: Some proposed treatments may result in an unacceptable risk of conflict with the public, First Nations or other stakeholders.
- **Potential for crop tree damage**: Heavy slash loading from motor-manual treatments could mechanically damage crop trees. It can be hard to spot crop trees in dense vegetation which can result crop tree damage. Brushing can increase the risk of root rot spreading. Slash loading or dead stems can also create fire risks.
- **Availability of crews**: It is increasingly difficult to attract workers to the silviculture industry and brushing is onerous physical work. Safety is also a factor as higher numbers of injury claims are associated with higher claim payments for brushing and weeding. Fewer people are engaging in this sector (Dilkina 2019). The area manually brushed, 11,600 ha in 2018, would have to double to treat the sprayed area, so manpower availability would be limiting.

Post-treatment effectiveness evaluation

s.13

s.13

Environmental Protection Strategies and Procedures

s.13

(including herbicide transportation, storing, mixing, loading, disposal) and the environmental safeguards in place regarding herbicide field application, including:

- Strategies to protect community watersheds and other domestic water sources

- Strategies to protect fish and wildlife, riparian areas, and wildlife habitat
- Pesticide free zones (PFZ)
- Species at Risk
- Strategies to prevent herbicide treatment of food intended for human consumption
- Pre-treatment inspection procedures for identifying treatment area boundaries
- Weather monitoring and strategies
- Procedures for maintaining and calibrating herbicide application equipment

GLOSSARY

s.13

FLNRORD	BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FRPA	Forest Range and Practice Act
FSP	Forest Stewardship Plan
FPPR	Forest Planning and Practices Regulation

s.13

PMP	Pest Management Plan
PMRA	Health Canada Pest Management Regulatory Agency
RESULTS	Reporting Silviculture Updates and Land Status Tracking System

s.13



info@fpinnovations.ca
www.fpinnovations.ca

OUR OFFICES

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
(514) 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
(604) 224-3221

Québec
1055 rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
(418) 659-2647

Begon, Stacey FLNR:EX

From: Hedges, Shawn FLNR:EX
Sent: November 8, 2019 2:18 PM
To: Ken Byrne; Pamela Matute
Cc: Berg, Shane FLNR:EX; Zacharias-Homer, Christa ENV:EX; MacDougall, Julie FLNR:EX; Psyllakis, Jennifer FLNR:EX; Mullan, Jonathan M ENV:EX; Bedford, Lorne FLNR:EX; Hughes, Neil FLNR:EX; Gordon, Steve M FLNR:EX
Subject: Redlined comments/suggested edits re: draft FPI glyphosate report
Attachments: Glyphosate 19.10.29 (Nov 6_19 Comments_Edits).docx

Ken, Pamela, as promised below, attached is a redlined version of the draft FPI glyphosate report I received October 29.

Edits/commentary by "Microsoft Office User" are from me. I use a MacBook and for some reason it doesn't identify me. The other comments are from Jonathan Mullan from Env. Regardless, everything should be rather self-explanatory, but if questions arise please don't hesitate to jot me an email. I'm away next week but will no doubt given my messages a scan or two.

Other than that, thanks for the good work.

Myself and my colleague look forward to receipt of your final polished report when ready.

_____

Shawn Hedges, RPF
Director, Sustainability & Forestry
Office of the Chief Forester
Forests, Lands, Natural Resource Operations & Rural Development
Cellular (250) 896-9911

From: Ken Byrne
Date: Friday, November 1, 2019 at 9:23 AM
To: Shawn Hedges , Pamela Matute
Subject: Re: Jim Hunt

Hello Shawn,

Thank you very much.[s.22] but will be in the office on November 18. Hopefully we can make that work. Please let me know at your convenience.

Pam, hopefully you will also be available to meet on November 18 with Shawn after they review the Glyphosate report.

Thanks very much,
Ken

From: Hedges, Shawn FLNR:EX
Sent: November 1, 2019 7:31 AM

To: Ken Byrne
Subject: Re: Jim Hunt

[EXTERNE - EXTERNAL]

Ken, further to below, I'll be working with my colleagues to review/discuss your latest draft report and hope to have a redlined edit back to you by no later than Friday November 8. We can discuss further if you/Pam like after I get back from a wee vacation Nov 11-15.

In the meantime, I've completed any initial read of the draft. I have some schoolmarm edits and a few minor questions, but first impressions are favourable. We'll see what my colleagues impressions are when I discuss it with them next Wednesday Nov 6.

SH

FPInnovations

info@fpinnovations.ca
www.fpinnovations.ca

REVIEW OF GLYPHOSATE USE IN BC FORESTRY

BRITISH COLUMBIA

Jim Hunt, Lead Scientist

Pamela Matute, Researcher

FPInnovations

Current glyphosate use in BC forestry was reviewed including peer-reviewed forest science on the impacts of glyphosate use on forests as well as input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishment of forest stands post-harvest.

Project number: 301013763

ACKNOWLEDGEMENTS

This project was contracted by the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

APPROVER CONTACT INFORMATION
Shawn Hedges
Director, Sustainability and Forestry

shawn.hedges@gov.bc.ca

REVIEWERS
Ken Byrne, Manager, Fibre Supply

AUTHOR CONTACT INFORMATION
Jim Hunt
Lead Scientist, Fibre Supply
james.hunt@fpinnovations.ca
(604) 222-5618

Disclaimer to any person or entity as to the accuracy, correctness, or completeness of the information, data, or any analysis thereof contained in this report, or any other recommendation, representation, or warranty whatsoever concerning this report.

Follow us

Table of contents

Executive Summary 1
1 Introduction 3
2 Use of Glyphosate in BC Forests 4
2.1 Regulatory Framework 4
2.1.1 Free Growing 4
2.1.2 Herbicides 5
2.2 Why is Glyphosate Used? 6
2.2.1 Site Preparation 7
2.2.2 Plantation Survival 7
2.2.3 Crop Tree Productivity 7
2.2.4 Invasive Species 7
2.3 How is glyphosate used? 8
2.3.1 Area treated 8
2.3.2 Glyphosate Use at the Stand-Level 12
2.4 Treatment Costs 14
3 Impact of glyphosate use on non-timber values 15
3.1 Biodiversity 15
3.1.1 Broadleaf Tree Species 15
3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide 15
3.1.1.2 RESULTS Analyses 16
3.1.2 Non-Target Plant Communities 18
3.1.3 Aquatic Organisms 19
3.1.4 Wildlife 20
3.1.4.1 Toxicity 20
3.1.4.1 Forage quality and quantity 21
3.2 Soil and Water Quality 21
3.2.1 Glyphosate/AMPA fate in soils 21
3.2.2 Soil micro-organisms 22
3.2.3 Glyphosate/AMPA fate in water 22
3.3 Climate Change 23

3.4 Wildfire 24
3.5 First Nations 24
3.6 Public Use 25
4 Impacts on Timber Supply 26
4.1 I s.13 27
5 Recommendations 28
6 Conclusions 29
6 References 31
Appendix 1. International Assessments 43
Appendix 2. Stocking Standards and Survey Changes Related to Deciduous Management in BC 46
Appendix 3. Integrated Pest Management Principles 47
Glossary 54

EXECUTIVE SUMMARY

FPInnovations was contracted by the Office of the Chief Forester to undertake a review of current glyphosate use in BC forestry including peer-reviewed forest science on the impacts of glyphosate use on forests as well as input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishment of forest stands post-harvest. The report will inform future policy development and research needs with the main objective to promote the establishment of healthy and diverse forests.

The herbicide glyphosate is one of many vegetation management tools available to forest managers. As a tool for vegetation control, it is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. It is very effective because it is easily translocated within the target plant, usually killing it and reducing the brush hazard for multiple years after a single application, unlike other motor-manual vegetation control methods. Glyphosate application may target aggressive competition from broadleaved trees, shrubs and herbaceous vegetation.

Roughly 11,000 ha of crown land were treated with glyphosate in BC for silviculture in 2018. Total area treated with glyphosate was 7% of the area harvested in 2018 on BC crown land, and less than 0.5% of the area with outstanding reforestation obligations. In 2018, most (73%) of the glyphosate application occurred in the Omineca Natural Resource Region. Of all biogeoclimatic zones, the Sub-Boreal Spruce zone saw the most glyphosate use (76%). Glyphosate was primarily applied aerially (86%) while the remainder 14% was treated using ground-based methods.

Public concerns over the impacts of glyphosate use on the ecosystem is currently growing, particularly regarding ecosystem changes resulting from the control of broadleaf trees such as trembling aspen. A RESULTS (Reporting Silviculture Updates and Land Status Tracking System) analysis of deciduous stand components at free growing showed that in the Omineca, where most of the glyphosate application takes place, deciduous components accounted for 15-21% of the stand density in sites that were previously treated with glyphosate. Data also shows that in the BC interior, mixed deciduous stands have been increasing over time as a result of forest management activities.

A summary of the many studies regarding the impact of glyphosate on forest soils, water, non-target plant communities, and wildlife is presented. While impacts can vary with site characteristics, research has shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes to these communities are related to changes in vegetation structure and are transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. Recent research has found low but unexpected levels of glyphosate residue in plants one year following treatment, which may have implications on wildlife forage quality, plant physiology and traditional food and

medicine plant harvesting. While residue levels were non-toxic to humans and wildlife, little is known about their effect on forage quality and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

Glyphosate remains an important tool for establishing conifer or conifer-deciduous mixed stands and ensuring future timber supply. Glyphosate bans in other jurisdictions in Canada have resulted in significant struggles to meet timber objectives in the land base, highlighting glyphosate's important role in maintaining conifer productivity. Forest management in BC seeks to balance all values ascribed to the forest with the overarching objective of establishing and maintaining healthy and diverse forests. While more research is recommended on the identified knowledge gaps, glyphosate needs to be considered in the context of these values and objectives, and with perspective regarding the amount of area treated, the apparent transient effects on the site's ecology, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels.

1 INTRODUCTION

Public pressure to reduce the use of glyphosate has been increasing in British Columbia and other jurisdictions. In response, the Office of the Chief Forester for BC Ministry of Forests Lands, Natural Resource Operations and Rural Development's (FLNRORD) ~~of BC~~ contracted FPInnovations to undertake a review of current peer-reviewed forest science and best practices on glyphosate use in the BC forestry. Input from stakeholders was also solicited. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered[1]. The report will inform future policy development and research needs with the main objective to promote the establishment of healthy and diverse forests. s.13

s.13

Formatted: Not Highlight

s.13

Successful regeneration of forests after timber harvesting often requires control of competing vegetation which may cause mortality or reduced growth of established seedlings. Several vegetation management alternatives exist for this purpose, including s.13

s.13

Glyphosate-based herbicides are the most widely used in the world, largely due to their effectiveness, their safety for non-target species and the environment, and the development of glyphosate tolerant agricultural crops (Edge et al., 2014). Several factors support the use of this herbicide in forestry applications in BC:

- Ability to translocate within treated plants and control resprouting of perennial weeds;
- Generally favourable environmental profile, including binding in soils and rapid biodegradation in most soils, water and sediments;
- Specific mechanism of action, inhibiting an enzyme found only in plants;
- Low toxicity to animals; and
- Minimal impact on forest ecosystems (Rolando et al., 2017).

s.13

1 See Forest Planning and Practices Regulation Part 2, Division 1.

2 USE OF GLYPHOSATE IN BC FORESTS

2.1 Regulatory Framework

2.1.1 Free Growing

In BC, timber harvesting in public forests is regulated such that any harvested area must be reforested to an acceptable standard of free growing. The *Forest Range and Practices Act*[2] (FRPA) (sec 1) defines "free growing" as "*a stand of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees*". A free growing stand is expected to contribute to landscape objectives and to a sustainable long-term fibre supply.

Formatted: Font: Italic

The Forest Planning and Practice Regulation~~3~~ (FPPR) (Sec 44) addresses obligations to produce a free growing stand that meets applicable stocking standards approved in a Forest Stewardship Plan (FSP) by specified dates. Stocking standards are regulatory tools that ensure that the re-establishment of a forest stand post-harvest is aligned to large-scale objectives for the land base as set out in FSPs. Stocking standards specify regeneration requirements such as suitable tree species for the site, stand density, spacing, free growing height and ratio of crop tree height to surrounding competing vegetation.

Sec 46.11 of the FPPR indicates that these silvicultural obligations must be fulfilled on each hectare within the net area to be reforested, unless otherwise specified in an FSP. Mappable areas that do not meet stocking standards should not exceed 2 ha or 5% of the Standard Unit (SU) area. Under FPPR section 97.1, an obligation holder may be relieved of the obligation to meet stocking standards if they can prove that obligations have been met to the extent that is practicable.

Sec 26 (5) of the FPPR ~~Sec 26 (5)~~ also provides a mechanism to develop stocking standards in an FSP that are not consistent with current timber supply assumptions. The review test for sec~~tion~~ 26 (5) requires the Delegated Decision Maker to be satisfied that the regeneration date and stocking standards are reasonable, having regard for future timber supply and the set values ascribed to forest land.

Free growing surveys are the tool by which forest managers measure whether a stand meets free growing obligations. Survey methods, including quantification of shrub and broadleaf competition, are described in the Silviculture Surveys Procedures Manual[4]

Stocking standards and related guidance have evolved since the 1990s and continues to evolve to incorporate current understanding of resource issues (e.g. broadleaf species) and their

2 http://www.bclaws.ca/Recon/document/ID/freeside/00_02069_01

~~3 http://www.bclaws.ca/civix/document/id/lc/statreg/14_2004~~

4 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

impact on timber supply and other forest values. A summary of these developments is described in Appendix 2.

2.1.2 Herbicides

Health Canada's Pest Management Regulatory Agency (PMRA)[5] is responsible for regulating pesticide use in Canada to ensure they pose minimal risk to human health and the environment. Under authority of the Pest Control Products Act, Health Canada:

- registers pesticides after a stringent, science-based evaluation that ensures any risks are acceptable;
- re-evaluates the pesticides currently on the market on a 15-year cycle to ensure the products meet current scientific standards; and
- promotes sustainable pest management.

s.13

s.13

The *Integrated Pest Management Act* (IPMA) and Regulation[6] (IPMR) sets out the requirements for the use and sale of pesticides in BC[7]. The BC Ministry of the Environment and Climate Change Strategy (ENV) promotes Integrated Pest Management (IPM) and environmental stewardship and ensures compliance with the IPM Act and Regulations. Large scale pesticide programs (i.e. >20 ha/year of treatment area) that require IPM must have a confirmed Pest Management Plan (PMP). PMPs document how the standards set in the IPMR will be implemented regarding

s.13

Formatted: Font: Italic

s.13

IPM is a process for managing pest populations. In a forestry context where competing vegetation is considered as a pest or weed, the following integrated vegetation management elements would apply:

- Planning and managing ecosystems to prevent organisms from becoming weeds;
- Identifying weed problems and potential weed problems;
- Monitoring populations of weeds and weed complexes;
- Using injury thresholds[8] in making treatment decisions;
- Select pest treatment methods based on:

5 https://www.canada.ca/en/health-canada/corporate/about-health-canada/branches-agencies/pest-management-regulatory-agency.html

6 https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management/pesticide-use/regulations-consultations

7 https://www2.gov.bc.ca/assets/gov/environment/pesticides-and-pest-management/business-and-industry/forestry_review.pdf

[8] The injury threshold is the level at which pest numbers are high enough to cause unacceptable injury or damage.

- Consideration of practical alternatives to herbicide use,
- Protection of human health and the environment; and

- Evaluating the effectiveness of weed management treatments.

Herbicides are rarely the only integrated vegetation management method used and are generally used in conjunction with other methods. Examples of best practices for implementing integrated vegetation management are included in Appendix 3.

2.2 Why is Glyphosate Used?

Managing competing vegetation is an essential part of reforestation efforts after forest harvesting. In B.C., vegetation management focuses on highly aggressive herbaceous complexes such as fireweed or bluejoint grass, and competitive deciduous trees such as red alder, broadleaf maple and trembling aspen. Targeted vegetation control is used for two main reasons in silviculture:

Commented [MOU9]: Used as "BC" (not "B.C.") elsewhere

- to maintain plantation survival, and
- to meet free growing obligations that ensure stand productivity and sustainable future timber supply.

s.13

Depending on the developmental stage of a plantation and its brush complex, glyphosate may be used to: clear a planting site of pre-established brush, to reduce seedling competition in order to ensure plantation survival, or to meet free-growing requirements that ensure long-term productivity and timber supply, particularly where specific timber species and outcomes are being managed for.

2.2.1 Site Preparation

s.13

2.2.2 Plantation Survival

Plantations on sites with aggressive competing vegetation complexes can fail within a year without effective vegetation management. In these cases, interventions are often needed to avoid excessive seedling mortality and plantation failure (Comeau and Harper, 2009; Biring et al., 2003; Comeau et al., 1999). This application of glyphosate is particularly important with herbaceous vegetation complexes for which mechanical cutting is not effective, such as bluejoint reed grass (*Calamagrostis canadensis*). Bluejoint reed grass is a serious competitor in northeastern BC, where it often colonizes sites after harvest forming thick colonies that can prevent establishment of shrub and tree species for upwards of 25 years if left uncontrolled (Dunbar et al., 2011). Glyphosate application on these sites can suppress the growth of competitive vegetation ~~for~~ enabling tree seedlings to become established.

2.2.3 Crop Tree Productivity

s.13

s.13 A single application of glyphosate during the first few years after planting in high-brush sites has been shown to effectively improve conifer growth 9 to 20 years later in a wide range of plant communities in various ecosystems in ~~British Columbia~~BC (Harper et al., 1997a, b; Whitehead and Harper 1998; Biring et al., 1999, s.13 Biring and Hays-Byl 2000; Simard 2001; Harper et al., 2005; Boateng et al., 2006; Macadam and Kabzems 2006). There is substantial variation in the magnitude of reported growth gains as they are dependent on type, intensity and duration of vegetation competition; in certain cases, the effects have been found to be significant but can also be short-term (Comeau et al., 1999; Heineman et al., 2005; Comeau and Harper, 2009).

Commented [MOU12]: ?

2.2.4 Invasive Species

While the focus of this report is on use of glyphosate in BC silviculture, glyphosate may also be used in forests to control the spread of noxious and invasive weeds across the province. FRPA sec 47 indicates that a person carrying out a forest or range practice must carry out measures to prevent the introduction or spread of prescribed species of invasive plants as listed in the invasive species regulation. The BC Weed Control Act requires all land occupiers to control the spread of noxious weeds on their land or premises.

s.13

s.13

2.3 How is glyphosate used?

2.3.1 Area treated

Data from the RESULTS s.13
database s.13
s.13 11,000 ha of crown land were treated with glyphosate for silviculture in 2018[11] with 86% sprayed aerially and 14% sprayed using ground-based methods (Figure 1). s.13
s.13
s.13 The area sprayed in 2018 was 0.044% of the 25 M ha available for harvesting in BC and 0.44% of the tenured area on crown land that has an outstanding reforestation obligation.

s.13

s.13

9 https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/invasive-species/pest-management/2019_herbicide_summary_for_control_of_knotweeds_on_crown_lands.pdf

10 https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-reporting-results

[11] This includes aerial and ground-based brushing and site preparation treatments excluding 'basal spray' and 'stem bark spray' silviculture methods which do not apply to glyphosate. It may include some triclopyr application that was reported as Backpack treatment method. Private land is not included.

s.13

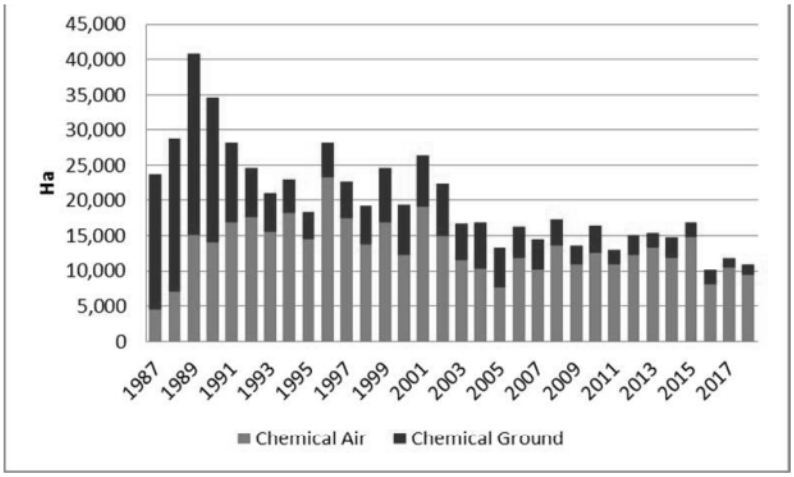


Figure 1. Area sprayed with glyphosate for silviculture in BC.

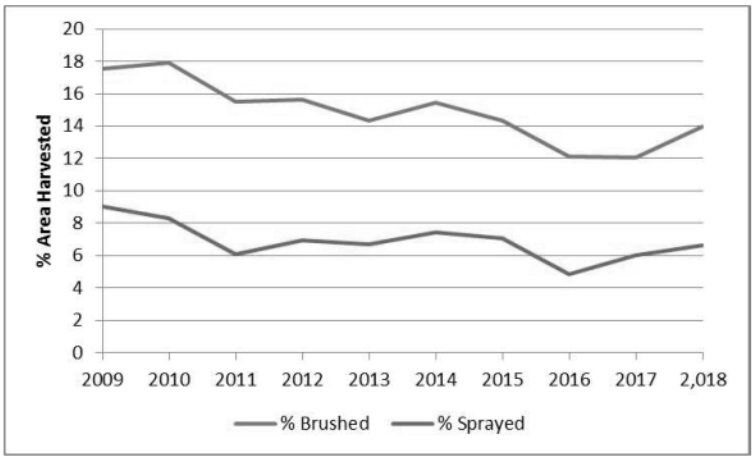


Figure 2. The percentage of harvested area that is brushed with alternative methods and sprayed with glyphosate.

9

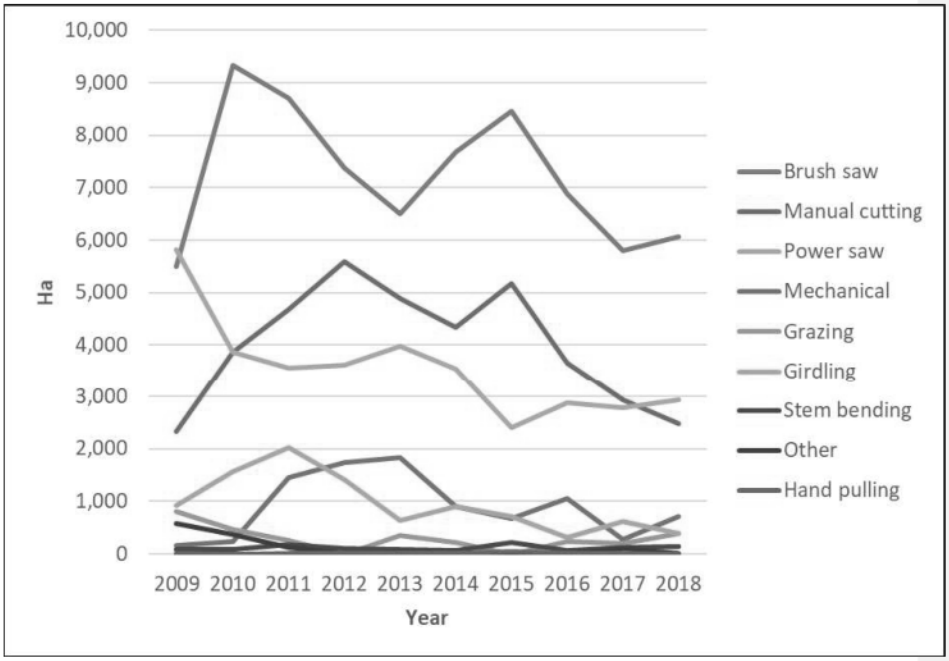


Figure 3. Area brushed with non-chemical methods.

Most of the spraying occurred in the Omineca Natural Resource Region (73%) followed by the Northeast Region (11%) (Table 1). The Prince George Timber Supply Area (TSA) comprised 68% of the total provincial area sprayed with glyphosate in 2018. Aerial applications made up 96% of the spray programs in those Regions. Small aerial programs also occurred in Thompson-Okanagan and South Coast Regions. Small ground-based programs occur in all regions with the largest occurring in the South Coast Region. The proportions of area harvested that were sprayed with glyphosate range from 11-15% for the South Coast, Northeast and Omineca regions, while the remaining regions in the province were less than 3% of the harvested area (Table 1).

Table 1. Area sprayed with glyphosate by Natural Resource Region (ha) in 2018.

s.13

The biogeoclimatic (BGC) zones (Meidinger and Pojar 1991) where most of the glyphosate application occurred are the Sub-Boreal Spruce (76%) and Boreal White and Black Spruce (9%) zones (Table 2)s.13 The drier SBS subzones (dry warm (dw) and moist cool (mk)) are dominated by aspen while the wetter subzones (wet cool (wk) and very wet cool (vk)) are dominated by herbaceous vegetation.

Table 2. Area sprayed with glyphosate by BGC zone (ha) in 2018

s.13

s.13

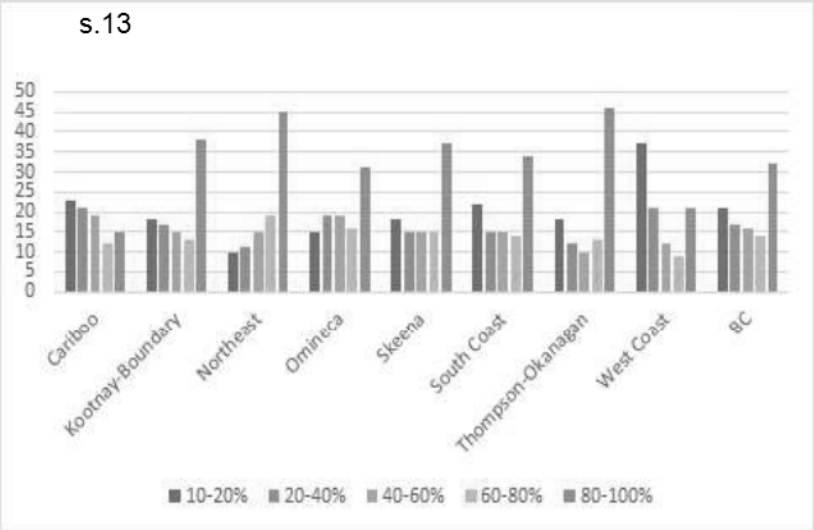
2.3.2 Glyphosate Use at the Stand-Level

Glyphosate is generally used in a targeted portion of the total reforestation area, as opposed to covering entire cutovers. s.13

s.13

[12] This analysis included blocks that were treated with herbicide one time only

s.13



s.13

In contrast with agriculture and other common land uses where areas are sprayed repeatedly,
s.13
s.13 The percentage of blocks treated more than twice was 32% for ground-based and 11% for aerial in BC. The Coast regions had a higher proportion of retreatments s.13
s.13

s.13

	Ground			Aerial		
	Number of Treatments					
	1	2	>2	1	2	>2
	%			%		
Cariboo	74	20	6	83	16	1
Kootenay	44	42	14	100	0	0
Northeast	64	25	12	53	30	17
Omineca	89	10	1	68	24	8
Skeena	79	11	10	70	15	15
South Coast	41	29	30	79	21	0
Thompson	75	17	8	45	33	22
West Coast	24	19	58	63	25	11
BC	47	21	32	65	25	11

Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species. Commonly targeted vegetation complexes in the SBS, where most of the glyphosate application takes place, are trembling aspen, mixed shrub, fireweed and wet alder. The BWBS zone is dominated by aspen/poplar and reed grass complexes (Comeau et al., 1996).

Target species are indicated on brushing prescriptions developed from operational surveys. A licensee in the Prince George region has indicated that 53% of the 2018 aerial spray area targeted aspen while 47% targeted herbaceous/shrub competition. Aggregated data of which complexes are targeted the most by glyphosate application is currently lacking. More work is required to understand how glyphosate use is distributed amongst particular vegetation complexes or species to understand how and why glyphosate is used, and what the impact of not using glyphosate would be.

2.4 Treatment Costs

Treatment costs vary considerably depending on location, access, treatment intensity, availability of crews and equipment, logistics, etc. BCTS and ~~Licensees~~ licensees reported that manual treatments ($700-$1,200/ha) are twice the cost of glyphosate treatments ($300-$500/ha) and require at least two treatments. The cost of achieving free growing on a site that needs vegetation control ranges from $900-$2,100/ha more when using manual treatments. An example of treatment costs to attain free growing with and without glyphosate in the Prince George region was provided by BCTS s.13 Assuming the s.13 example is representative and applying an average cost difference of $1,400/ha to the 11,000 ha area that was sprayed in 2018, the cost of not using glyphosate for silviculture is estimated at $15.4 M per year.

s.13

s.13

s.13 costs are an important consideration - safety, access, crew availability, treatment windows and various operational factors also affect the selection of treatment options discussed in Appendix 3.

3 IMPACT OF GLYPHOSATE USE ON NON-TIMBER VALUES

s.13

3.1 Biodiversity

The FPPR indicates the objective set by the BC government for wildlife and biodiversity at the landscape level is, without unduly reducing the supply of timber from British Columbia's forests and to the extent practicable, to design areas on which timber harvesting is to be carried out that resemble, both spatially and temporally, the patterns of natural disturbance that occur within the landscape.

3.1.1 Broadleaf Tree Species

Mixedwood forests provide various ecological, social, and non-timber values; have significant value in shaping forest ecology, stand structure, and function; and exert a strong influence on forest diversity and resilience (Harper 2014)s.13
s.13

3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide

On sites where it exists pre-harvest, aspen regenerates aggressively from suckering after a stand-replacing event such as fire or harvesting (Frey et al., 2003). This is particularly the case in the boreal and sub-boreal mixedwoods that make up large portions of Central and Northeastern B.C., where research has shown that in order to establish a conifer crop, vegetation management is often required to counter the suckering of aspen following harvest (Wood and von Althen 1993; Cole et al., 2003; Pitt and Bell 2005; Boateng et al., 2006).
s.13

While those studies focused on deciduous composition within herbicide-treated areas, it's important to note that glyphosate is not generally applied to entire harvest units (see section 2.3.2), and that the total elimination of competitive vegetation is not a silvicultural objective of

conifer-release programs (Bell and Newmaster 2002). In B-C-, vegetation management treatments, including glyphosate application, are carried out only in the portions of a harvest unit where they are deemed necessary for conifer survival or to meet free-growing stocking standards in each standard unit as per Sec 46.11 of the FPPR.

3.1.1.2 RESULTS Analyses

A 2008 Forest and Range Evaluation Program (FREP) review of species diversity pre- and post-harvest in B-C- found that the amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods (BCMFLNROR 2008). Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing, a 3,000% increase.

Commented [MOU23]: Did you mean to say FLNRORD?

An up-to-date RESULTS query of stand composition for all stands declared free growing following herbicide treatment (aerial and ground-based) was prepared for this report by FLNRORD.s.13

s.13

In the Northeast and Omineca Regions, where most herbicide treatments take place, the average number of deciduous stems/ha at free growing following aerial herbicide treatments were 864 and 445 stems/ha, or 27% and 15% of the total stand species compositions. s.13

s.13

In general, ground-based application resulted in a slightly higher number and percentage of deciduous stems at free growing compared with aerial application for most regions.s.13

s.13

s.13

s.13

s.13

3.1.2 Non-Target Plant Communities

3.1.2.1 Diversity of plant communities

A review of 12 studies by Sullivan and Sullivan (2003) found that species richness and diversity of nontarget vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies report that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment (Sullivan et al., 1998a, Freedman et al., 1993; Lautenschlager and Sullivan 2002, Bell and Newmaster 1998; Hawkins et al., 2013; Comeau and Fraser, 2018). In many cases, herbaceous vegetation abundance, diversity and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank (Sullivan and Sullivan, 2003; Kabzems and Harper, 2015).

While broadcast aerial spraying of glyphosate is sometimes seen as a blunt vegetation management tool, studies have found that it doesn't target all vegetation equally. On sites with a vertical vegetation structure (comprised of aspen, shrubs, and forbs), one study found that the majority of the spray was deposited in the aspen canopy (68% of the nominal application rate), while shrubs and herbs captured approximately 25% and 12% of the nominal application rate, which may further help explain their quick recovery (Thomson et al., 1997).

Only two of the twelve studies analyzed by Sullivan and Sullivan (2003) observed an overall reduction in species richness of shrubs after glyphosate application (Santillo et al., 1989a; Sullivan et al., 1988). Santillo et al. (1989) found that species richness was decreased by 50% and

Commented [MOU24]: ?

30% for shrubs and herbs respectively one year after treatment and continued to be lower in the treatment units after three years. The control sites in this study however were at a different successional stage than the glyphosate treatment units (Santillo et al., 1989a). Sullivan et al. (1988) likewise observed a reduction in shrub species richness 5 years after treatment.

s.13

3.1.2.1 Persistence of glyphosate/AMPA in plant tissue

Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions (Gomes et al., 2014) due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels s.13 s.13 in some surviving perennial forest plants for at least 1 year (Wood 2019). Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality, however some translocation into shoots and fruit was observed in select plants (Wood 2019). s.13 s.13

s.13

s.13

3.1.3 Aquatic Organisms

Amphibian populations are declining around the world (Houlahan et ~~at~~ al., 2000), and chemical contaminants released to aquatic environments have been listed as the second most important threat to amphibians after habitat loss (Edge et ~~at~~ al., 2011). s.13 s.13

s.13

Numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development (Edge et al., 2012, Lanctot et al., 2013, Edge et al., 2014b), the expression of genes related to larval development (Lanctot et al., 2013), or juvenile amphibian survival (Edge et al., 2011, 2013). This is likely due to the short (but environmentally realistic and relevant) exposure duration (generally less than 96 hours) and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands (Edge et al., 2012, 2014b, Baker et al., 2016).

A watershed level study in coastal BC found temporary stress effects and minor mortality (2.6%) in caged coho salmon smolt in an experimentally over-sprayed tributary and the main stream below the sprayed area immediately post glyphosate application. No acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident coho (Legris and Couture, 1991; Feng et al., 1990; Reynolds et al., 1993). Similarly, no effects on

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: Not Highlight

growth, behaviour or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment (Morgan and Kiceniuk, 1992).

s.13

3.1.4 Wildlife

3.1.4.1 Toxicity

Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates (Durkin et al., 2003; Giesy et al., 2000; PMRA, 2015). Some uncertainty remains in the literature regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage. While observed residue levels were non-toxic to mammals, the effects of chronic sub-lethal exposure to mammals are not yet well-understood and require more research (Wood, 2019; Mesnage et al., 2015; Kissane and Sheppard, 2017)

Effects on terrestrial wildlife communities, like in aquatic ecosystems, are primarily linked to the changes in vegetation cover and forage quality. As such, species responses are highly variable and reflect individual habitat preferences. Studies on wildlife response to habitat alteration from glyphosate application have shown no effect, short-term negative effects and positive effects on different wildlife species (Guynn et al., 2004). All in all, studies suggest that species richness and diversity of small and large mammals s.13 songbirds and invertebrates remain within the range of natural variation and that changes are transient (Sullivan and Sullivan 2003).

3.1.4.1 Forage quality and quantity

Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline (Kuzyk et al., 2018).
s.13

s.13 The long-term impact of glyphosate use on habitat selection by moose is not well understood however. Biring et al. (1999) reported decreased forage abundance and use 12 years after glyphosate application in a BWBS site. However, Newton reported a 46% decrease in forage the year following glyphosate application, but a 660% increase in forage at year 8 compared to the control (Newton et al., 1989), and some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls (Raymond et al., 1996; Eschholz et al., 1996). These impacts must also be considered in relation to the area treated annually and its distribution over the landscape (Lautenschlager and Sullivan 2002).

The effects of glyphosate's chelating properties on forage quality and nutrient availability are poorly understood. s.13 properties of glyphosate allow it to bind macro- and micronutrients (in particular iron, manganese, zinc, copper and nickel) which can s.13 impact uptake and availability in plants treated with glyphosate (Mertens et al., 2018). These micronutrients are particularly important to ungulates such as moose, whose sensitivities to mineral imbalances (in particular Cu) have been implicated in moose population decreases in Alaska, Sweden and Minnesota (Custer et al., 2004; Flynn et al., 1977; O'Hara et al., 2001; Frank et al., 1994).

Studies on nutrient uptake by surviving plants in agricultural settings after glyphosate application has provided contradictory accounts (Gomes et al., 2014), in some cases a reduced uptake of micronutrients by plants has been found (Eker et al., 2006; Tesfamariam et al., 2009; Cakmak et al., 2009). While in others (Duke et al., 2012; Duke et al., 2018) no effect on micronutrient content was found. More research is required on whether glyphosate application leads to a reduced micronutrient content specifically in wildlife forage, and whether this is implicated in the population declines of moose in BC.

3.2 Soil and Water Quality

3.2.1 Glyphosate/AMPA fate in soils

After application, glyphosate is largely immobilized in the soil due to its strong sorption characteristics that allow it to bind with soil particles and organic materials. Once glyphosate reaches the soil, the main pathway for glyphosate dissipation in soil is microbial degradation, as many species of soil microorganisms can use glyphosate as their soil carbon source (Durkin, 2003). One of the main compounds released during the microbial breakdown process, ~~aminomethylphosphonic acid (~~AMPA~~)~~, is likewise adsorbed to soils and biodegraded, yet considered to be a mild phytotoxin (Reddy et al., 2004; Gomes et al., 2014) with relatively unknown long-term consequences on soil organisms and plants.

Commented [MOU31]: Acronym previously defined.

Sorption and degradation processes are highly dependent on microbial activity and soil composition (Székács and Darvas, 2012). The rate of sorption and degradation of both glyphosate and AMPA vary greatly in agricultural applications, with half-lives ranging between a few days to several months, and even up to a year (Székács and Darvas, 2012). While it has been argued that the short growing season in northern climates may restrict degradation, North American studies in forest applications have found that the time for 50% dissipation (DT50) in litter and soil is 8 to 19 days, and 5 to 40 days respectively (Newton et al., 1984; Newton et al., 1994; Thompson et al., 2000; Feng and Thompson, 1990; Hagner et al., 2019).

3.2.2 Soil micro-organisms

Soil organisms play a crucial role in nutrient cycling and maintaining ecosystem productivity. Research on the effect of glyphosate in micro-organisms in laboratory studies has been contradictory. Laboratory studies have found exposure to glyphosate formulations may either decrease (Druille et al., 2013; Zaller et al., 2014; Tanney and Hutchinson, 2010; Estok et al., 1989; Sanogo et al., 2000; Diaz et al., 2003) or rarely stimulate (Laatikainen and Heinonen-Tanski 2002; Diaz et al., 2003) proliferation of certain fungal species. Laboratory studies on cultured microorganisms are likely to overestimate toxicity effects (Estok et al., 1989), however. Field studies of the effect of glyphosate application on forest soil organisms and microbial processes are limited and their findings often contradictory. Some detrimental effects on fungal communities and nutrient cycling have been documented by Munson et al. (1993) and Vitousek et al. (1992). Similarly, annual applications of glyphosate over a ~~five~~ five-year period in an Ontario plantation have resulted in reduced microbial biomass, microbial carbon, soil organic carbon ratio, which indicates a reduced capacity of the ecosystem to maintain its nutrient reservoir (Ohtonen et al., 1992). In contrast, other field studies have found minimal or no effect on microbial processes or fungal community structures (Busse et al., 2001; Houston et al., 2002; Haney et al., 2002; Stratton and Steward, 1992; Chakravarty and Chatarpaul, 1990), while others have found a short-term increase in microbial activity caused by the breakdown of glyphosate and AMPA (Wardle and Parkinson 1990, Mijangos et al., 2009, Ratcliff et al., 2006, Haney et al., 2002). The extent of the variation in results suggests more research is needed in forest applications of glyphosate to better understand direct effects on microbial communities. Research should look at effects on individual species and the indirect impacts resulting from these changes in the ecosystem.

3.2.3 Glyphosate/AMPA fate in water

s.13

s.13 The main ways that glyphosate could end up in aquatic ecosystems are by drift onto non-target areas or by soil particle mobilization after a storm event in the hours following glyphosate application (Rolando 2017). These risks may be minimized in field operations using electronic guidance systems, low drift nozzles, and meteorological monitoring of wind speed, temperature and humidity (Thompson et al., 2012). In the field, studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken (Thompson et al., 2004, Feng and Thompson 1990; Gluns et al., 1989; Adams et al., 2007).

If movement into water sources occurs, most North American field studies in streams and wetlands have shown DT50 for glyphosate of less than 5 days, with no detectable residues after

s.13

s.13

The primary mechanisms behind the rapid breakdown or reduction of glyphosate in the water column are adsorption into benthic or suspended sediments, microbial breakdown of glyphosate and its breakdown products, and downstream dilution. Glyphosate does persist longer in oligotrophic water bodies or those that are cold, deep and low in microbial activity. Residues have been detected in benthic sediments of these systems for up to 18 months after application (Feng et al., 1990; Newton et al., 1994; Newton et al., 1984)

3.3 Climate Change

The Intergovernmental Panel on Climate Change notes that "in the long-term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit" (Nabuurs et al., 2007). Vegetation management (including, but not limited to, glyphosate application) can affect carbon sequestration due to its impact on vegetation structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows the establishment of a woody crop delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools.

When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species. Mixedwood stands comprised of spruce and aspen are likely to have a higher yield than either pure spruce or pure aspen stands because of differences in shade tolerance, phenology, rooting patterns, and physical space occupied by different sized canopies (Gough et al., 2019, McCulloch and Kabzems 2009). Retaining between 1,000 and 10,000 stems/ha of aspen is expected to increase total stand production by approximately 20% relative to a pure spruce stand, but this will be at the expense of spruce volume (Kabzems et al., 2007). Harper and Roach (2014) similarly report that in a modeled mixedwood, the total stand volume is higher in a spruce-aspen mixedwood compared to pure spruce or pure aspen stands.

This effect varies with species, however. Growth and yield models in the SBS show that total stand volumes in lodegepole pine-aspen stands are not different from pure aspen or pure pine stands (Harper, 2015). In all cases, the increase of deciduous volume is at the expense of conifer volume (Kabzems et al., 2007; Harper and Roach, 2014; Harper, 2015).

Forest soils are the largest carbon pool in boreal and temperate ecosystems, often storing greater amounts of carbon than living biomass and coarse woody debris (Heath et al., 2003). Laganiere et al., (2017) found that aspen trees stored less carbon in the forest floor and similar amounts in the mineral soil relative to conifers. However, their study also showed that soil organic carbon stock under aspen is more stable, rendering it more protected against environmental changes and soil disturbances.

A source of uncertainty in determining the difference in carbon sequestration between mixedwoods and pure conifer stands stems from the shorter lifespan of deciduous trees compared to conifers, which ultimately affects the amount of time that a stand can act as a carbon sink (Harper and Roach, 2014).

3.4 Wildfire

Vegetation management (including, but not limited to, glyphosate application) has the potential of altering the amount of deciduous trees left on a site after regeneration. Deciduous stands often act as natural fire breaks. In summer months, deciduous stands moderate microclimates, inhibit wind movement, help maintain lower air temperature and higher humidity and maintain soil and surface fuel moisture longer into the fire season (Chesterman, 1997). s.13
s.13

The physical properties of aspen, in particular, resist intense fire behaviour (Alberta 2012), making it a popular choice for fuel treatments in the wildland urban interface throughout North America (Gray 2018, Shepperd et al., 2006). Usually, fire does not get carried into the crowns of deciduous stands due to the absence of ladder fuels. Consequently, fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires (Alexander and Lanoville, 2004). The FBP system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous[13] or leaf-on mixedwood stands. Amongst deciduous trees, poplars show the most fire resistance s.13
s.13

s.13

Table 5. Fire resistance of broadleaved species (BCMFLNRORD 2019).

Fire resistance/resilience	Broadleaved species
High	Balsam poplar, black cottonwood
High-Moderate	Gary oak, bigleaf maple
Moderate	Trembling aspen, red alder, paper birch
Low	Arbutus

3.5 First Nations

Some First Nations across BC have expressed concern over the use of glyphosate in forests. Some of these concerns relate to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated. Chief Ron Ignace (Skeetchestn Indian Band) has indicated that he considers the spraying of herbicide "an act of cultural genocide, because you are killing our foods and medicines."[14] The McLeod Lake Indian Band passed a Band Council resolution in July 2019 that reaffirms the Band's zero tolerance for herbicide, pesticide, insecticide and chemical fertilizer use within the traditional

[13] During spring months before leaf-out in deciduous stands, the grass has the potential to dry out rapidly in the absence of canopy cover, creating a higher surface fire potential until green-up and leaf-on occurs.

14 https://acuriouslookatpoliticsinbc.blogspot.com/2019/09/adam-olsen-skeetchestn-indian-band.html?fbclid=IwAR3kXSjKGMzGu6V5qs4Gxvu9l06PdbVbL5TtjdfWvallemumCz0TiAsRnaQ

territory. The resolution indicates that glyphosate is deemed carcinogenic and has a direct impact on wildlife, ecosystems and water sources. Where there is doubt concerning the science about herbicides, there can be an inclination toward the precautionary principle.

Two-way education, communication, collaboration and joint problem solving between stakeholders is key to reaching agreements about land use. Traditional plant users should, for example, take into consideration that the presence of glyphosate does not indicate toxicity (Wood, 2019) or that plant diversity, richness and abundance is not generally not affected in the years following application. Similarly, forest managers need to acknowledge and communicate uncertainty regarding minor effects of glyphosate use. There is mounting evidence for example that Glyphosate/AMPA may persist in low levels in some perennial plants (Wood, 2019), and that it may also disrupt the creation of some plant secondary compounds, some of which may be the compounds responsible for medicinal effects in traditional medicines (Gomes et al., 2014).

s.13

s.13

- Designating no spray areas
- Prioritizing manual treatments
- Prioritizing backpack instead of aerial application
- Prioritizing spot spray around individual stems
- Increasing buffers
- Leaving untreated patches
- Providing alternative gathering sites
- Providing additional notification and signage
- Adjusting treatment schedules to avoid disrupting First Nation activities

3.6 Public Use

Forest managers are faced with mounting public pressure over the safety of glyphosate use (Thomson and Pitt, 2011). Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping or hiking. The Canada Pest Management Regulatory Agency's review on glyphosate (PMRA 2017) has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health. This applies to people that may come in contact to glyphosate from food or water, by handling the product or by entering treated sites.

There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues (including game species such as moose, deer and hare) (Lautenschlager, 1992; Legris and Couture, 1991; Newton et al., 1984). Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue (Wood, 2019). Where detected, glyphosate residue levels averaged 0.79 ppm (highest level detected was 4 ppm). From a food consumption perspective, 0.1 ppm is the maximum residue level (MRL) allowed for non-designated food in Canada, although this value ranges from 0.08 to 40 for specific foods.

s.13

Formatted: Not Highlight

s.13

4 IMPACTS ON TIMBER SUPPLY

Vegetation control, including but not limited to glyphosate application, is in some cases necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests. Vegetation management is one key tool to meet these objectives.

Glyphosate is used in this context because of its cost-effectiveness compared to manual vegetation control methods. Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked (NSR) area particularly problematic areas with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

In Canada, decisions to not use chemical herbicides have been taken in Quebec and Nova Scotia. In Quebec, a provincial ban of glyphosate use on Crown land took effect in 2001 after severe public pressure and a series of public consultations. Forest regeneration would focus on early planting of tall stock and intensive manual brushing. Since then, plantation establishment and tending costs in Quebec have frequently exceeded $5,000/ha due to planting large stock and as many as three manual brushing treatments (Labbé et al., 2014). Dampier et al. (2006) reported that cost per cubic metre of wood tripled when conifer release was performed by motor-manual methods rather than aerial application of herbicide.

s.13

An audit of plantations in Nova Scotia after a decision was made not to use herbicides yielded similar findings. Following a survey of untreated plantations, results showed 87% of conifer plantations were considered failures (with less than 60% stocking), and only 3% met free growing standards 6-8 years post-harvest (Nicholson, 2007).

In BC, meeting free growing stocking standards ensures that sustainable timber supply is achieved. In cases where aggressive competing vegetation cannot be overcome to the extent that is practicable in order to meet free growing requirements, licensees may request relief from reforestation obligations under FPPR sec 97.1. Increasing the challenge to meet reforestation obligations on a broad scale may increase the risk for reduced plantation performance with significant timber supply impacts, such as in the case of Quebec.

4.1 s.13

s.13

There are ongoing efforts to further develop standards that facilitate deciduous management in the context of overall forest management objectives. One example is the inclusion of fire stocking standards in the Wildland Urban Interface, including the establishment and management of deciduous species to reduce fire behaviour in areas near communities and infrastructure.[17] In another example, a Hardwood Management Strategy was developed in 2008 to facilitate management of red alder, bigleaf maple and birch in the Coast Region.[18] Wildlife stocking standards are also being developed and regional guidance is available.

15 http://www.fsjpilotproject.com/documents/SFMPappend2016/Appendix_6_Reforestation_Strategy_Stocking_Standards_and_Crop_Tree_Requirements.pdf

16 https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/stocking-standards

17 https://www.for.gov.bc.ca/hfp/silviculture/Fire%20Management%20Stocking%20Standards%20Guidance%20%20Document%20March%202016.pdf

18https://www.for.gov.bc.ca/rco/stewardship/CRIT/docs/Hardwood%20Management%20in%20the%20Coast%20Forest%20Region%20(final%20July11V2).pdf

s.13

5 RECOMMENDATIONS

s.13

19 https://www.bcfpb.ca/wp-content/uploads/2019/07/SR58-Tactical-Forest-Planning.pdf

20 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-strategies/2018_final_merritt_iss_tactical_plan_v11.pdf

s.13

6 CONCLUSIONS

Glyphosate is one of many vegetation management tools available to forest managers. It is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. Forest managers are faced with mounting public pressure over the perceived environmental impacts of forestry applications of glyphosate. In particular, concerns over the removal of broadleaf tree species from the landscape and the consequent impacts on risk of wildfire, wildlife habitat, climate change, etc. A review of current inventory data however shows that stands that have been treated with glyphosate retain 15-21% deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.

Field studies have also shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals s.13
songbirds and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.

s.13

30

6 REFERENCES

Adams, G.W., Smith, T., and Miller, J.D. 2007. The Absence of Glyphosate Residues in Wet Soil and the Adjacent Watercourse after a Forestry Application in New Brunswick, Northern Journal of Applied Forestry, Volume 24, Issue 3.

Alexander, M.E., and Laneville, R.A. 2004. The International Crown Fire Modelling Experiment fuel treatment trials [abstract]. Page 222 in R.T. Engstrom, K.E.M. Galley, and W.J. de Groot (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

Baker, L. F., Mudge, J. F., Houlahan, J. E., Thompson, D. G. and Kidd, K. A. 2014. The direct and indirect effects of a glyphosate-based herbicide and nutrients on Chironomidae (Diptera) emerging from small wetlands. Environmental Toxicology and Chemistry 33:2076-2085.

Baker, L. F., Mudge, J.F, Thompson, D.G, Houlahan, J.E and Kidd, K.E. 2016. The combined influence of two agricultural contaminants on natural communities of phytoplankton and zooplankton. Ecotoxicology 25:1021-1032.

BC Ministry of Forests, Lands and Natural Resource Operations. 2008. Tree species composition and diversity in British Columbia. FREP Report #14.

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development. 2018, Silviculture Surveys Procedures Manual Regen Delay, Stocking and Free Growing Surveys plus Alternative Survey Methodologies. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

Bell, F. W. and Newmaster, S.G. 2002. The effects of silvicultural disturbances on the diversity of seed-producing plants in the boreal mixedwood forest. Can J. For Res. Vol 32 (7), p 1180-1191. https://digitalcommons.usu.edu/aspen_bib/389

Biring, B.S. and Hays-Byl, W.J. 2000. Ten-year Conifer and Vegetation Responses to Glyphosate Treatment in the SBSdw3. BC Ministry of Forests Extension Note 46.

Biring, B.S., Hays-Byl, W.J. and Hoyles, S.E., 1999. *Twelve-year conifer and vegetation responses to discing and glyphosate treatments on a BWBSmw backlog site*. British Columbia, Ministry of Forests Research Program.

Biring, B.S.; Comeau, P.G.; Fielder, P. 2003. Long-term effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in Southern British Columbia. Annals of Forest Science 60(7):681-690.14.

Boateng J.O., Heineman, J.L., McClarnon, J. and Bedford, L. 2006.Twenty year responses of white spruce to mechanical site prepara-tion and early chemical release in the boreal region of northeastern British Columbia. Can. J. For. Res. 36: 2386–2399.

Bureau du forestier en chef. 2015. Succes des plantations. Avis du Forestier en chef. FEC-AVIS-04-2015, Roberval, Quebec, 22 p. +annexes. http://forestierenchef.gouv.qc.ca/wpcontent/uploads/2015/12/fec-avis-04-201S.pdf

Busse, M.D., Ratcliff, A.W., Stestak, C.J., Powers, R.F. 2001. Glyphosate toxicity and the effects of long-term vegetation control on soil microbial communities. Soil Biology & Biochemistry, Vol. 33: 1777-1789.

Cakmak, I., Yazici, A., Tutus, Y. and Ozturk, L., 2009. Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium, and iron in non-glyphosate resistant soybean. European Journal of Agronomy, 31(3), pp.114-119.

CCME (Canadian Council of Ministers of the Environment). 2012. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Glyphosate. In: Canadian environmental quality guidelines, Canadian Council of Ministers of the Environment, Winnipeg.

Chakravarty, P. and Chatarpaul, L., 1990. Non-target effect of herbicides: II. The influence of glyphosate on ectomycorrhizal symbiosis of red pine (Pinus resinosa) under greenhouse and field conditions. *Pesticide science*, *28*(3), pp.243-247.

Chesterman, D.A., 1997. Microclimate of aspen forests. University of Alberta M.Sc. thesis.

Cole, E., Youngblood, A. and Newton, M. 2003.Effects of competing vegetation on juvenile white spruce (Picea glauca(Moench)Voss) growth in Alaska. Ann. For. Sci. 60: 1–11

Comeau, P.G., Harper, G., Blache, M.E., Boateng, J.O. and Gilkeson, L., 1996. Integrated forest vegetation management: Options and applications.

Comeau, P.G., Biring, B.S. and Harper, G.J., 1999. Conifer response to brushing treatments: a summary of British Columbia data. Extension Note, British Columbia Ministry of Forests, (41), p.12.

Comeau, P.G., Biring, B.S., and Harper, G.J. 2000. Effectiveness of Repeated Manual Cutting and Glyphosate for Release of Engelmann Spruce from Mixed-Shrub Herb Vegetation. Western Journal of Applied Forestry 15(3):154-162. http://dx.doi.org/10.1093/wjaf/15.3.154

Comeau, P. and Fraser, E., 2018. Plant Community Diversity and Tree Growth Following Single and Repeated Glyphosate Herbicide Applications to a White Spruce Plantation. Forests, 9(3), p.107.

Comeau, P.G. and Harper, G.J., 2009. Effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia Year 15 results. The Forestry Chronicle, 85(4), pp.583-592.

Connor, J.F. and McMillan, L.M., 1990. *Winter utilization by moose of glyphosate-treated cutovers*. Ontario Ministry of Natural Resources, Northwestern Ontario Forest Technology Development Unit.

Custer, T.W., Cox, E., & Gray, B. 2004. Trace elements in moose (Alces alces) found dead in Northwestern Minnesota, USA. Science of the Total Environment, 330(1): 81-87.

Dampier, E.E., Bell, F.W., St-Amour, M., Pitt, D.G., Luckai, N.J. 2006. Cutting versus herbicides: Tenth-year volume and release cost-effectiveness of sub-boreal conifer plantations. Forestry Chronicle 82(4):521-528. https://pubs.cif-ifc.o rg/doi/10.5558/tfc82521-4

Diaz, G., Carrillo, C., and Honrubia, M. 2003. Differential responses of ectomycorrhizal fungi to pesticides in pure culture. Cryptogam.: Mycol. 24: 199–211.

Druille, M., Cabello, M.N., Omacini, M. and Golluscio, R.A., 2013. Glyphosate reduces spore viability and root colonization of arbuscular mycorrhizal fungi. *Applied Soil Ecology*, *64*, pp.99-103.

Duke, S.O., Lydon, J., Koskinen, W.C., Moorman, T.B., Chaney, R.L. and Hammerschmidt, R., 2012. Glyphosate effects on plant mineral nutrition, crop rhizosphere microbiota, and plant disease in glyphosate-resistant crops. Journal of agricultural and food chemistry, 60(42), pp.10375-10397.

Duke, S.O., Rimando, A.M., Reddy, K.N., Cizdziel, J.V., Bellaloui, N., Shaw, D.R., Williams, M.M. and Maul, J.E., 2018. Lack of transgene and glyphosate effects on yield, and mineral and amino acid content of glyphosate-resistant soybean. Pest management science, 74(5), pp.1166-1173.

Dunbar, J., McCulloch, L. and Kabzems, R., 2011. Bluejoint Stand Establishment Decision Aid. Journal of Ecosystems and Management, 11(3).

Durkin, PR. Glyphosate - Human health and ecological risk assessment report. Syracuse Environmental Research Associates Inc, Fayetteville NY 2003.

Edge, C. B., Gahl, M.K., Pauli, B.D, Thompson, D.G. and Houlahan, J.E. 2011. Exposure of juvenile green frogs (Lithobates clamitans) in littoral enclosures to a glyphosate-based herbicide. Ecotoxicology and environmental safety 74:1363-1369.

Edge, C. B., M. K. Gahl, D. G. Thompson, and J. E. Houlahan. 2013. Laboratory and field exposure oftwo species of juvenile amphibians to a glyphosate-based herbicide and Batrachochytrium dendrobatidis. Science of the Total Environment 444:145-152.

Edge, C. B., D. G. Thompson, C. Hao, and J. E. Houlahan. 2012. A silviculture application of the glyphosate-based herbicide VisionMAX to wetlands has limited direct effects on amphibian larvae. Environmental Toxicology and Chemistry 31:2375-2383.

Edge, C., M. Gahl, D. Thompson, C. Hao, and J. Houlahan. 2014a. Variation in amphibian response to two formulations of glyphosate-based herbicides. Environmental Toxicology and Chemistry 33:2628-2632.

Edge, C., D. Thompson, C. Hao, and J. Houlahan. 2014b. The response of amphibian larvae to exposure to a glyphosate-based herbicide (Roundup WeatherMax) and nutrient enrichment in an ecosystem experiment. Ecotoxicology and Environmental Safety 109:124-132.

Edginton, A.N., Sheridan, P.M., Stephenson, G.R., Thompson, D.G. and Boermans, H.J., 2004. Comparative effects of pH and Vision® herbicide on two life stages of four anuran amphibian species. *Environmental Toxicology and Chemistry: An International Journal*, *23*(4), pp.815-822.

Ehrentraut, G., and Brantner, K. 1990. Vegetation management by manual and mechanical means in Alberta boreal forests. For. Chron. 66: 366–368.

Eker, S., Ozturk, L., Yazici, A., Erenoglu, B., Romheld, V. and Cakmak, I., 2006. Foliar-applied glyphosate substantially reduced uptake and transport of iron and manganese in sunflower (Helianthus annuus L.) plants. Journal of agricultural and food chemistry, 54(26), pp.10019-10025.

Eremko, R.D. 1986. The effects of the aerial application of Roundup on water quality in the Nicoamen River watershed. Unpubl.report for B.C. Min. For. & Lands, Lillooet District.

Eschholz, W.E., Servello, F.A., Griffith, B., Raymond, K.S., and Krohn, W.B. 1996. Winter use of glyphosate-treated clearcuts by moose in Maine. J. Wildl. Manage.60: 764–769

Estok, D., Freedman, B., and Boyle, D. 1989. Effects of the herbicides 2,4-D, glyphosate, hexazinone, and triclopyr on the growth of three species of ectomycorrhizal fungi. Bull. Environ. Contam. Toxicol. 42(6): 835–839. doi:10.1007/BF01701623. PMID: 2743015.

Feng, J.C. and D.G. Thompson. 1990. Fate of glyphosate in a Canadian forest watershed. 2. Persistence in foliage and soils. J. Agric. Food. Chem. 38:

Feng, J.C., Thompson, D.G., Reynolds, P.E. 1990. Fate of glyphosate in a Canadian forest watershed. 1. Aquatic residues and off-target deposit assessment. J. Agric. Food Chem. 1990, 38, 1110-1118.

Flynn, A., Franzmann, A.W., Arneson, P.D. and Oldemeyer, J.L., 1977. Indications of copper deficiency in a subpopulation of Alaskan moose. The Journal of Nutrition, 107(7), pp.1182-1189.

Folmar, L.C., Sanders, H.O. & Julin, A.M. Arch. Environ. Contam. Toxicol. (1979) 8: 269. https://doi.org/10.1007/BF01056243

Frank, A., Galgan, V. and Petersson, L.R., 1994. Secondary copper deficiency, chromium deficiency and trace element imbalance in the moose (Alces alces L.): effect of anthropogenic activity. Ambio (Sweden).

Freedman, B., Morash, R., and MacKinnon, D. 1993. Short-term changes in vegetation after the silvicultural spraying of glyphosate herbicide onto regenerating clearcuts in Nova Scotia, Canada. Can. J. For. Res.23:230D-2311.

Frey, B.R., Lieffers, V.J., Landhäusser, S.M., Comeau, P.G. and Greenway, K.J., 2003. An analysis of sucker regeneration of trembling aspen. Canadian Journal of Forest Research, 33(7), pp.1169-1179.

Giesy J.P., Dobson S., Solomon K.R. (2000) Ecotoxicological Risk Assessment for Roundup® Herbicide. In: Ware G.W. (eds) Reviews of Environmental Contamination and Toxicology. Reviews of Environmental Contamination and Toxicology, vol 167. Springer, New York, NY

Gluns, D.R. 1989. Herbicide residue in surface water following an application of Roundup® in the Revelstoke Forest District. B.C. Ministry of Forests and Lands. RR 88001-NE.

Goldsborough, L.G. and Beck, A.E., 1989. Rapid dissipation of glyphosate in small forest ponds. *Archives of Environmental Contamination and Toxicology*, *18*(4), pp.537-544.

Goldsborough, L.G. and D.J. Brown. 1993. Dissipation of glyphosate and aminomethylphosphonic acid in water and sediments of boreal forest ponds. Environ. Toxicol. Chem. 12:1139-1147

Gomes, M.P., Smedbol, E., Chalifour, A., Hénault-Ethier, L., Labrecque, M., Lepage, L., Lucotte, M. and Juneau, P., 2014. Alteration of plant physiology by glyphosate and its by-product aminomethylphosphonic acid: an overview. *Journal of experimental botany*, *65*(17), pp.4691-4703.

Gough, C.M, J.W. Atkins, R.T. Fahey and B.S. Hardaman. 2019. High rates of primary production in structurally complex forests, Ecology {2019). DOI: 10.1002/ecy.2864

Gray, R.W. 2018. Trembling aspen stands as firebreaks: what options are available for stimulating aspen stand expansion. City of Cranbrook, UBCM Fuel Management Pilot Program. https://wfca.ca/wpcontent/ uploads/2018/06/Trembling-Aspen-Stands-as-Firebreaks FINAL-REPORT.pdf

Guynn DC, Guynn ST, Wigley TB, Miller DA. 2004. Herbicides and forest biodiversity: what do we know and where do we go from here? WIldlife Society Bulletin. 2004; 32(4):1085-92.

Haney, R.L., Senseman, S.A. and Hons, F.M., 2002. Effect of Roundup Ultra on microbial activity and biomass from selected soils. *Journal of Environmental Quality*, *31*(3), pp.730-735.

Hagner, M., J. Mikola, I. Saloniemi, K. Saikkonen, M. Helander. 2019. Finnish ecological sustainability study: Glyphosate-based Roundup herbicide has 'minor, transient' impacts on soil and animal health. Scientific Reports (9)1: 8540. doi.org/10.1038/s41598-019-44988-5

Harper, G.J. 2015. Lodgepole pine and trembling aspen mixedwoods: Growth and yield within 22 to 39 year old pine plantations of northern interior British Columbia. For. Chron. 91(5): 502-518. https://www.researchgate.net/publication/291424207_Lodgepole_pine_and_trembling_aspen_mixedwoods_Growth_and_yield_within_22_to_39_year_old_pine_plantations_of_northern_interior_British_Columbia

Harper, G. 2017. Lodgepole pine and trembling aspen competition: Neighbourhood studies within 22 to 39 year old pine plantations of northern British Columbia. Forestry Chronicle, 2017, 93{3): 226-240, https:// doi .org/10.5558/tfc2017 -031

Harper, G.; Roach, J. 2014. The role of broadleaf trees: impacts of managing boreal and sub-boreal mixedwood forests in British Columbia. Extension Note- British Columbia Ministry of Forests and Range 2014 No.110 pp.8 pp.

Harper, G.J., Biring, B.C. and Heineman, J. 1997. Mackay River Herbicide Trial: Conifer Response 9 Years Post-treatment. BC Ministry of Forest Research Branch. Research Report 11.

Harper, G.J., Comeau, P.G. and Biring, B. S. 2005. A comparison of herbicide and mulch mat treatments for reducing grass, herb, and shrub competition in the BC Interior Douglas-fir zone—

Ten-year results. Western Journal of Applied Forestry, Volume 20, Issue 3, July 2005, Pages 167–176.

Hart, D. and Comeau, P.G. 1992. Manual brushing for forest vegetation management in British Columbia: A review of current knowledge and information needs. B.C. Ministry of Forests, Forest Science Research Branch. Land Management Report Number 77.

Hawkins, C.D.B.; Dhar, A.; Lange, J. 2013. Vegetation management with glyphosate has little impact on understory species diversity or tree growth in a sub boreal spruce plantation—A case study. Plant Biosyst. 2013, 147, 105–114.

Health Canada Pesticide Management Regulatory Agency. 2017. Re-evaluation decision glyphosate RVD2017-01. https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/registration-decision/2017/glyphosate-rvd-2017-01.html

Health Canada Pesticide Management Regulatory Agency. 2019. Statement from Health Canada on glyphosate. https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

Heath, L.S., Kimble, J.M., Birdsey, R.A. and Lal, R., 2003. The potential of US forest soils to sequester carbon. *In: Kimble, JM; Heath, Linda S.; Birdsey, Richard A.; Lal, R., eds. The potential of US forest soils to sequester carbon and mitigate the greenhouse effect. Boca Raton: CRC Press: 385-394.*

Heineman, J.L., S.W. Simard, D.L. Sachs and W.J. Mather. 2005. Chemical, grazing, and manual cutting treatments in mixed herb-shrub communities have no effect on interior spruce survival or growth in southern interior British Columbia. Forest Ecology and Management. Vol *205, 1-3,* p 359-374. https:// doi .org/10.1016/j. foreco.2004.10.038

Hjeljord, O. and Gr⊘ nvold, S., 1988. Glyphosate application in forest—ecological aspects: VI. Browsing by moose (Alces alces) in relation to chemical and mechanical brush control. *Scandinavian Journal of Forest Research*, *3*(1-4), pp.115-121.

Houlahan, J.E., C.S. Findlay, B.R. Schmidt, AH Meyer and S.L. Kuzmin. 2000. Quantitative evidence for global amphibian population declines. Nature 404. 752-755.

Houston, A.P.C., Visser, S. and Lautenschlager, R.A., 2002. Response of microbial processes and fungal community structure to vegetation management in mixedwood forest soils. Canadian journal of botany, 76(12), pp.2002-2010.

Howe, C.M., Berrill, C.M., Pauli, B.D., Helbing, C.C., Werry, K. and Veldhoen, N. 2004. Toxicity of glyphosate-based pesticides to four North American frog species. Environmental Toxicology and Chemistry: No. 23, pp. 1928–1938.

Kabzems, R., A.L. Nemec, and C. Farnden. 2007. Growing trembling aspen and white spruce intimate mixtures: Early results (13-17 years) and future projections. BC Journal of Ecosystems and management 8(1):1-14. uri: http://www.forrex.org/publications/jem/ISS39/vol8 no1 artl.pdf

Kabzems R. and G.J. Harper. 2015. Conifer and vegetation responses to pre-planting applications of glyphosate and hexazinone on a boreal backlog site, Sx trial 82502g-2. Prov. B.C., Victoria, B.C. Tech. Rep. 087. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr087.htm

Kissane, Z. and Shephard, J.M., 2017. The rise of glyphosate and new opportunities for biosentinel early-warning studies. Conservation biology, 31(6), pp.1293-1300.

Kuzyk, G., Marshall, S., Procter, C., Schindler, H., Schwantje, H., Gillingham, M., Hodder, D., White, S. and Mumma, M., 2018. Determining factors affecting moose population change in British Columbia.

Laatikainen, T., and Heinonen-Tanski, H. 2002. Mycorrhizal growth in pure cultures in the presence of pesticides. Microbiol. Res. 157(2): 127–137. doi:10.1078/0944-5013-00139. PMID: 12002401.

Lautenschlager, RA. 1992. Effects of conifer release with herbicides on moose: browse production, habitat use, and residues in meat. Alces 28:215-222

Lautenschlager, R.A., Dalton, W.J., Cherry, M.L., and Graham, J.L. 1999. Conifer release alternatives increase aspen forage quality in northwestern Ontario. J. Wildl. Manage.63: 1320–1326.

Labbé, F., Lainesse, M., Nadeau, F-R., Prégent, G., Savary, A. 2014. Analyse de rentabilité économique des plantations d'épinette noire et blanche et de pin gris. Bureau de mise en marché des bois, Québec (Québec). https://www.bmmb.gouv.qc.ca/analyses-economiques/.

Laganiere, J.; Boca, A.; Van Miegroet, H.; Pare, D. 2017. A tree species effect on soil that is consistent across the species' range: the case of aspen and soil carbon in North America . Forests 8: 113.

Lanctot, C., L. Navarro-Martin, C. Robertson, B. Park, P. Jackman, B. D. Pauli, and V. L. Trudeau. 2014. Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frog (Litho bates sylvaticus) tadpoles. II: Agriculturally relevant exposures to Roundup WeatherMax® and Vision® under laboratory conditions. Aquatic Toxicology 154:291-303.

Lanctot, C., C. Robertson, L. Navarro-Martin, C. Edge, S. D. Melvin, J. Houlahan, and V. L. Trudeau. 2013. Effects of the glyphosate-based herbicide Roundup WeatherMax® on metamorphosis of wood frogs (Litho bates sylvaticus) in natural wetlands. Aquatic toxicology 140-141:48-57.

Lautenschager, R.A. 1993. Response of wildlife to forest herbicide applications in northern coniferous ecosystems. Can. J. For. Res. 23: 2286-2299

Lautenschlager, R.A., and Sullivan, T.P. 2002. Effects of herbicide treatments on biotic components inregenerating northern forests. For. Chron.78: 1–37.

Legris, J.; Couture, G. Residus de Glyphosate dans le Gibier (Lievre, Orignal Qt cerf de Virginie) Suite a des Pulverisations en Milieu Forestier en 1988; Quebec Ministere des Forest, Direction de I' evaluation Environnementale: Charlesbourg, QC, Canada, 1991.

Lindgren, P.M.F., and T.P. Sullivan. 2001.1nfluence of alternative vegetation management treatments on conifer plantation attributes: abundance, species diversity, and structural diversity. For. Ecol. Manag. 142(1-3): 163-182

Macadam, A. and Kabzems, R. 2006. Vegetation Management Improves Early Growth of White Spruce More Than Mechanical Site Preparation Treatments, Northern Journal of Applied Forestry, Volume 23, Issue 1, March 2006, Pages 35–46, https://doi.org/10.1093/njaf/23.1.35

McCulloch, L. and R. Kabzems. 2009. British Columbia's northeastern forests: Aspen Complex Stand Establishment Decision Aid. BC Journal of Ecosystems and Management 10(2):51-58. www.forrex.org/publications/jem/ISS51/vol10 no2 art5.pdf

Meidinger and Pojar, 1991. Ecosystems of British Columbia. Special report Series 6, BC Ministry of Forests.

Mertens, M., Höss, S., Neumann, G., Afzal, J. and Reichenbecher, W., 2018. Glyphosate, a chelating agent—relevant for ecological risk assessment. Environmental Science and Pollution Research, 25(6), pp.5298-5317.

Mesnage, R., Defarge, N., De Vendômois, J.S. and Seralini, G.E., 2015. Potential toxic effects of glyphosate and its commercial formulations below regulatory limits. Food and Chemical Toxicology, 84, pp.133-153.

Mijangos, I., Becerril, J.M., Albizu, I., Epelde, L. and Garbisu, C., 2009. Effects of glyphosate on rhizosphere soil microbial communities under two different plant compositions by cultivation-dependent and-independent methodologies. *Soil Biology and Biochemistry*, *41*(3), pp.505-513.

Miller, D.T. 1985. Conifer release in the inland northwest - Effects p. 17-24 in weed control for forest productivity in the interior west. Symp Proce Spokane. WA February 5-7, 1985. Washington State University

Morgan, M.J., and J.W. Kiceniuk. 1992. Response of Rainbow trout to a two month exposure to Vision(!), a glyphosate herbicide. Bull. Environ. Contam. Toxicol. 48:772-780

Munson, A.D., Margolis, H.A. and Brand, D.G., 1993. Intensive silvicultural treatment: impacts on soil fertility and planted conifer response. *Soil Science Society of America Journal*, *57*(1), pp.246-255.

Nabuurs, J., Masera, 0., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., Elsiddig, E., FordRobertson, J., Frumhoff, P., Karjalainen, T., Krankina, 0., Kurz, W., Matsumoto, M., Oyhantcabal, W., Ravindranath, N., Sanz, M. Sanchez, T. and Zhang, X. 2007: Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group Ill to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. *Dave,* L.A. Meyer {eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NV, USA.

Navarro-Martin, L., C. Lanctot, P. Jackman, B. J. Park, K. Doe, B. D. Pauli, and V. L. Trudeau. 2014. Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frogs (*Litho bates sylvaticus*) tadpoles. 1: Chronic laboratory exposures to Vision Max®. Aquatic Toxicology 154:278-290.

Navratil, S., K. Branter and J. Zasada. 1991.Regeneration in the mixedwoods. InA. Shortreid (ed.). Proc. of the Symposium onNorthern Mixedwoods '89. Sept. 12-14, 1989, Fort St. John, BC.FRDA Report 164, Forestry Canada, Pacific Forestry Centre. pp.32–48.

Newsome, T.A. and J.L. Heineman. 2016. Adjusting free-growing guidance regarding aspen retention in the Cariboo-Chilcotin: research to operational implementation. Prov. B.C., Victoria, B.C. Tech Rep 102. https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/TR102.htm

Newton, M., Cole, E.C., Lautenschlager, R.A., White, D.E., and McCormack, M.L., Jr. 1989. Browse availability after conifer release in Maine's spruce-fir forests. J. Wildl. Manage.53: 643–649.

Newton, M,; Howard, K.M.; Kelpsas, B.R.; Danhaus, R.; Lottman, C.M.; Dubelman, S. 1984. Fate of glyphosate in an Oregon forest. Journal of Agricultural and Food Chemistry 32:1144-1151

Newton M, Howard KM, Kelpsas BR, Danhaus R, Lottman CM, Dubelman S. 1984. Fate of glyphosate in an Oregon forest. Journal of Agricultural and Food Chemistry. 1984; 32:1144-51

Newton M, Horner LM, Cowell JE, White DE, Cole EC. Dissipation of glyphosate and aminomethylphosphonic acid in North American forests. Journal of Agricultural and Food Chemistry. 1994; 42(8):1795-802

Nicholson, J. 2007. Survey of plantations established between 1998-2000 (6-8 years of age) on eastern Crown land without herbicides.: Nova Scotia Department of Natural Resources, Forest Management Planning, Forest Research Report 83, 27 p

O'Hara, T.M., Carroll, G., Barboza, P., Mueller, K., Blake, J., Woshner, V. and Willetto, C., 2001. Mineral and heavy metal status as related to a mortality event and poor recruitment in a moose population in Alaska. Journal of Wildlife Diseases, 37(3), pp.509-522.

Ohtonen, R., Munson, A. and Brand, D., 1992. Soil microbial community response to silvicultural intervention in coniferous plantation ecosystems. *Ecological Applications*, *2*(4), pp.363-375

Perala, D.A., 1985. Using glyphosate herbicide in converting aspen to conifers. Research Paper, North Central Forest Experiment Station, USDA Forest Service, (NC-259).

Pesticide Management Regulatory Agency, 2015. Glyphosate revaluation decision RVD2015-1. Health Canada.

Pesticide Management Regulatory Agency, 2017. Glyphosate revaluation decision RVD2017-1. Health Canada.

Pitt, D.G. and Bell, F.W., 2005. Juvenile response to conifer release alternatives on aspen-white spruce boreal mixedwood sites. Part I: Stand structure and composition. The Forestry Chronicle, 81(4), pp.538-547.

Pitt, D.G., R.G. Wagner and W.D. Towill. 2004a.Ten years of veg-etation succession following ground-applied release treatments in young black spruce plantations. North. J. Appl. For. 21(3): 123–134

Pitt, D.G., Mihajlovich, M. and Proudfoot, L.M., 2004b. Juvenile stand responses and potential outcomes of conifer release efforts on Alberta's spruce aspen mixedwood sites. The Forestry Chronicle, 80(5), pp.583-597.

Raymond, K.S., Servello, F.A., Griffith, B., and Eschholz, W.E. 1996. Winter foraging ecology of moose onglyphosate-treated clearcuts in Maine. J. Wildl. Manage.60: 753–763

Ratcliff, A.W., Busse, M.D. and Shestak, C.J., 2006. Changes in microbial community structure following herbicide (glyphosate) additions to forest soils. *Applied Soil Ecology*, *34*(2-3), pp.114-124.

Reddy, K.N., Rimando, A.M., Duke, S.O. 2004. Aminomethylphosphonic acid, a metabolite of glyphosate, causes injury in glyphosate-treated, glyphosate-resistant soybean. Journal of Agricultural and Food Chemistry 52, 5139–5143

Reynolds, P .E., Scrivener, J.C., Holtby, LB. and Kingsbury, P.D., 1993. Review and synthesis of Carnation Creek herbicide research. The Forestry Chronicle, 69(3), pp.32.3-330.

Rolando, C.A.; Baillie, B.R.; Thompson, D.G.; Little, K.M . 2017. The risks associated with glyphosate-based herbicide use in planted forests. Forests 8(6): 208-233. https://www.mdpi.com/1999-4907/8/6/208

Rzymski, P., Klimaszyk, P., Kubacki, T. and Poniedziałek, B. 2013. The effect of glyphosate-based herbicide on aquatic organisms – a case study. Limnological Review. 13(4):215-220

Sanogo, S., Yang , X.B., and Scherm, H. 2000. Effects of herbicides on Fusarium solanif. sp. glycines and development of sudden death syndrome in glyphosate-tolerant soybean. Phytopathology, 90(1): 57–66. doi:10.1094/PHYTO.2000.90.1.57.PMID:18944572.

Santillo, D.J., Leslie, D.M., Jr., and Brown, P.W. 1989a. Responses of small mammals and habitat to glyphosate application on clearcuts. J. Wild. Manage. 53: 164-172.

Shepperd, Wayne D.; Rogers, Paul C.; Burton, David; Bartos, Dale L. 2006. Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada. Gen. Tech. Rep. RMRS-GTR-178. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station 122 p.

Simard, S. 2001. Effects of Operational Brushing on Conifers and Plant Communities in the Southern Interior of British Columbia: Results from PROBE 1991-2000, PRotocol for Operational Brushing https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh48.pdf

Simard, S. and A. Vyse. 2006 Trade-offs between competition and facilitation: a case study of vegetation management in the interior cedar-hemlock forests of southern British Columbia. Canadian Journal of Forest Research, 2006, 36(10): 2486-2496, https://doi.org/10.1139/x06-150

Simard, S. and A. Vyse. 2006 Trade-offs between competition and facilitation: a case study of vegetation management in the interior cedar-hemlock forests of southern British Columbia. Canadian Journal of Forest Research, 2006, 36(10): 2486-2496, https://doi.org/10.1139/x06-150

Sullivan, T.P. and D.S. Sullivan. 2003. Vegetation management and ecosystem disturbance impact of glyphosate herbicide on plant and animal diversity in terrestrial ecosystems. Environ. Rev. 2013: 11:37-59.

Sullivan TP, Sullivan OS. Vegetation management and ecosystem disturbance: impact of glyphosate herbicide on plant and animal diversity in terrestrial systems. Environmental Review. 2003; 11:37-59.

Székács, A. & Darvas, B., 2012. Forty years with glyphosate. in Herbicides - Properties, Synthesis and Control of Weeds, M. N. A. E.-G. Hasaneen, Ed., InTech, Rijeka, Croatia, 2012.

Tanney, J. B., & Hutchison, L. J. 2010. The effects of glyphosate on the in vitro linear growth of selected microfungi from a boreal forest soil. Canadian journal of microbiology, 56(2), 138-144.

Taylor, S.W., R.G. Pike and M.E. Alexander. 1996. Field guide to the Canadian forest fire behaviour prediction (FPB) system. FRDA Handbook 012. https://www.for.gov.bc.ca/hfd/pubs/Docs/Frh/Frh012.pdf

Tarazona, Jose V.; Court-Marques, Daniele; Tiramani, Manuela; Reich, Hermine; Pfeil, Rudolf; lstace, Frederique;Crivellente, Federica (April3, 2017). "Giyphosate toxicity and carcinogenicity: a review of the scientific basis of the European Union assessment and its differences with IARC". Archives of Toxicology. 91 (8): 2723-2743.

Tesfamariam, T., Bott, S., Cakmak, I., Römheld, V. and Neumann, G., 2009. Glyphosate in the rhizosphere—Role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants. European journal of agronomy, 31(3), pp.126-132.

Thiffault, N. & Roy, V. 2011. Living without herbicides in Québec (Canada): historical context, current strategy, research and challenges in forest vegetation management. Eur J Forest Res (2011) 130: 117. https://rd.springer.com/article/10.1007/s10342-010-0373-

Thompson, D.G. and Pitt, D.G., 2011. Frequently asked questions (FAQs) on the use of herbicides in Canadian Forestry. *forest*, *13*, p.14.

Thompson DG, Pitt DG, Buscarini TM, Staznik B, Thomas DR. 2000. Comparative fate of glyphosate and triclopyr herbicides in the forest floor and mineral soil of an Acadian forest regeneration site. Canadian Journal of Forest Research. 30:1808-16.

Thompson DG, Pitt DG, Staznik B, Payne NJ, Jaipersaid D, Lautenschlager RA, et al., 1997. On-target deposit and verticle distribution of aerially released herbicides. For. Chron. 73(1):47-59.

Thompson, D.G, Wojtaszek, B.F., Staznik, B., Chartband, D.T., Stephenson, R. 2004. Chemical and biomonitoring to assess potential acute effects of VisonR herbicide on native amphibian larvae in forest wetlands. Environ Toxicol Chem 2004;23:843– 9.

Thompson, D., Leach, J., Noel, M., Odsen, Sand Mihajlovich, M. 2012. Aerial forest herbicide application: comparative assessment of risk mitigation strategies in Canada. For. Chron. 88(2) 176-184.

Wan, M.T., Watts, R.G. & Moul, D.J. 1989. Effects of different dilution water types on the acute toxicity to juvenile pacific salmonids and rainbow trout of glyphosate and its formulated products. Bull. Environ. Contam. Toxicol. (1989) 43: 378. https://doi.org/10.1007/BF01701872

Wardle, D.A. and Parkinson, D., 1990. Influence of the herbicide glyphosate on soil microbial community structure. Plant and Soil, 122(1), pp.29-37.

Whitehead, R.J and Harper, G.J. 1998. A comparison of four treatments for weeding Engelmann spruce plantations in the Interior Cedar Hemlock Zone of British Columbia: ten years after treatment. Canadian Forest Service Information report (Pacific Forestry Centre); BC-X-379

Wood, J.E. and F.W. von Althen. 1993. Establishment of whitespruce and black spruce in boreal Ontario: Effects of chemical site preparation and post-planting weed control. For. Chron. 69:554–560.

Wood, J.L. 2019. The presence of glyphosate in forest plants with different life strategies one year after application. Canadian Journal of Forest Research, 2019, 49(6): 586-594, https://doi.org/10.1139/cjfr-2018-0331

Zaller, J.G., Heigl, F., Ruess, L. and Grabmaier, A., 2014. Glyphosate herbicide affects below ground interactions between earthworms and symbiotic mycorrhizal fungi in a model ecosystem. Scientific reports, 4, p.5634.

APPENDIX 1. INTERNATIONAL ASSESSMENTS

Various international expert panels and regulators have reviewed glyphosate and its effect on human health. The consensus among national pesticide regulatory agencies and scientific organizations is that labeled uses of glyphosate have demonstrated no evidence of human carcinogenicity (Tarazona et al., 2017).

IARC

In March 2015, the World Health Organization's (WHO) International Agency for Research on Cancer (IARC), consisting of 17 experts from 11 countries, classified glyphosate as "probably carcinogenic in humans" based on epidemiological studies, animal studies, and in vitro studies[21]. This was based on "limited" evidence of cancer in humans (from real-world exposures that actually occurred) and "sufficient" evidence of cancer in experimental animals (from studies of "pure" glyphosate). "Limited" evidence means that a positive association has been observed between exposure to the agent and cancer but that other explanations for the observations (called chance, bias, or confounding) could not be ruled out.

IARC also concluded that there was "strong" evidence for genotoxicity, both for "pure" glyphosate and for glyphosate formulations[22].

EFSA

The European Food Safety Authority (EFSA) of the European Union (EU) concluded in Oct. 2015 that "the substance is unlikely to be genotoxic (i.e. damaging to DNA) or to pose a carcinogenic threat to humans"[23].

Glyphosate was not proposed to be classified as carcinogenic under the EU regulation for classification, labelling and packaging of chemical substances. In particular, all the Member State experts but one agreed that neither the epidemiological data (i.e. on humans) nor the evidence from animal studies demonstrated causality between exposure to glyphosate and the development of cancer in humans. A supplementary document clarified that while carcinogenic glyphosate-containing formulations may exist, studies "that look solely at the active substance glyphosate do not show this effect[24].

21 https://www.iarc.fr/featured-news/media-centre-iarc-news-glyphosate/

22 https://monographs.iarc.fr/wp-content/uploads/2018/06/mono112-10.pdf

23 http://www.efsa.europa.eu/en/efsajournal/pub/4302

24 http://www.efsa.europa.eu/sites/default/files/4302_glyphosate_complementary.pdf

Joint FAO/WHO

The WHO and FAO Joint committee on pesticide residues issued a report in 2016 stating the use of glyphosate formulations does not necessarily constitute a health risk and giving admissible daily maximum intake limits (one milligram/kg of body weight per day) for chronic toxicity[25].

EPA

In 2017, the American Environmental Protection Agency (EPA) classified glyphosate as "not likely to be carcinogenic to humans"[26]. The Agency's assessment found no other meaningful risks to human health when the product is used according to the pesticide label.

ECHA

In March 2017, the Committee for Risk Assessment of European Chemicals Agency (ECHA) concluded that the available scientific evidence did not meet the criteria to classify glyphosate as a carcinogen, as a mutagen or as toxic for reproduction. However, it was classified as causing serious eye damage and toxic to aquatic life with long lasting effects[27].

APVMA

In 2017 the Australian Pesticides and Veterinary Medicines Authority (APVMA) reviewed the IARC monograms and other international assessments and concluded that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans[28]. APVMA provides a good on-line overview of various studies and issues as well as an explanation of the IARC assessment[29].

California

Agreeing with the IARC classification, California listed glyphosate as a known carcinogen on July 7, 2017, under Proposition 65 law, which would require indicating this carcinogenicity hazard on the product label of glyphosate-based herbicide products. However, in response to a legal claim by an agricultural coalition including the National Association of Wheat Growers, Monsanto Corporation and farmer groups, the U.S. District Court issued a preliminary injunction against this evaluation on the basis that the classification by IARC claims glyphosate only probably carcinogenic, while apparently all other regulatory and governmental bodies found the opposite, including the US EPA[30].

Canada

In 2015 Health Canada's Pest Management Regulatory Agency (PMRA) released a Proposed Re-evaluation Decision document on glyphosate[31]. This consultation document described the registration process for the use of herbicides in Canada and summary of the science evaluated

25 https://www.who.int/foodsafety/areas_work/chemical-risks/JMPR_2016_Report_May.pdf

26 https://www.epa.gov/pesticides/epa-releases-draft-risk-assessments-glyphosate

27 https://echa.europa.eu/-/glyphosate-not-classified-as-a-carcinogen-by-echa

28 https://apvma.gov.au/sites/default/files/publication/26561-glyphosate-final-regulatory-position-report-final_0.pdf

29 https://apvma.gov.au/node/13891

30 https://www.frontiersin.org/articles/10.3389/fenvs.2018.00078/full

31 http://publications.gc.ca/collections/collection_2015/sc-hc/H113-27-2015-1-eng.pdf

and the reasons for the proposed re-valuation decision. Input comments were solicited. Registered pesticides are re-evaluated by PMRA on a cyclical basis to ensure they meet modern health and environment safety standards and continue to have value. In April, 2017, Health Canada reapproved glyphosate. The Re-evaluation Decision document[32] summarizes the agency's final decision on glyphosate, the reasons for it and PMRA's response to comments received. An evaluation of the available scientific information found that products containing glyphosate do not present risks of concern to human health or the environment when used according to the revised label directions. As a requirement for the continued registration of glyphosate uses, new risk reduction measures were required for the end-use products registered in Canada. These included a restricted-entry period of 12 hours for agricultural uses, directions to apply when potential for drift into areas of human activity is minimised, environmental hazard statements, spray buffer zones, precautionary statements and use restrictions to reduce runoff to aquatic areas.

Following Canada Health's re-evaluation decision of 2017, eight notices of objection were received. There were also public concerns about the validity of the science as indicated in the so called 'Monsanto Papers'. On January 11, 2019, Health Canada issued a statement indicating that after a thorough scientific review, objections to glyphosate use could not be scientifically supported when considering the entire body of relevant data[33].

32http://publications.gc.ca/collections/collection_2017/sc-hc/H113-28/H113-28-2017-1-eng.pdf

33 https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

APPENDIX 2. STOCKING STANDARDS AND SURVEY CHANGES RELATED TO DECIDUOUS MANAGEMENT IN BC

2007: Recognizing the autecology of the competition species, specifically shrub and herb compared to broadleaf species (deciduous), and the effects of these specific competitors on managed coniferous stands;

2007: Using improved free growing decision-making tools, via the quadrant method to evaluate free growing and 'potentially' free growing trees at the plot level, considering:

• site series specific competition thresholds;

• competition thresholds specific to the silvics of managed crop species.

This is a more refined evaluation method in the Coast, North and South Areas, when compared to simply evaluating competition within a 1 m cylinder with standard crop to brush ratios, as used in the past.

2009: Employing regionally developed brush competition assessments, specific to many BEC variants in the three Cariboo Timber Supply Areas (TSAs) based on empirical data collected by silviculture researchers. This neighbourhood concept has led to a greater flexibility in crop trees being assessed as free growing when intermixed and overtopped by broadleaf competition. As well, certain BEC variants in the Cariboo consider broad leaf competition as 'non-deleterious', thus not affecting their status as free growing;

2011: Developing new Broadleaf Forest Health Free Growing Damage Criteria, used to assess the acceptability of broadleaves as free growing, given these deciduous species are specified as crop trees in an approved Forest Stewardship Plan;

2018: Expanding the 'non-deleterious' definition of broadleaf competition, in conifer managed stands, to all site series within the IDFdk4 and SBPSxc BEC variants within the three Cariboo TSAs.

APPENDIX 3. INTEGRATED PEST MANAGEMENT PRINCIPLES

Elements of Integrated Vegetation Management include:

1. Prevention

2. Pest Identification

3. Seedling and Vegetation Monitoring

4. Injury Thresholds and Treatment Decisions

5. Treatment Options and Selection Criteria

6. Post-Treatment Effectiveness Evaluation

Prevention

Prevention of vegetation competition issues can be done through:

- **Site preparation:** The intent of site preparation is to reduce the impacts of growth limiting factors that might inhibit seedling establishment or growth potential.
- **Planting:** Stock with high genetic worth can improve survival performance of planted seedlings. Similarly, large seedling stock that is tall with good diameter is better suited to compete for light and can withstand higher brush hazards.
- **Species selection:** Species selection is made based on the ecological suitability of a species to the specific site conditions on an area. Additional considerations include immediate and long-term forest health factors, future forest products, volume and value, climate change, and consistency with the Timber Supply Analysis.
- **Regeneration delay:** Seedlings that are quickly established are more likely to compete successfully with problematic vegetation. Especially on brush prone sites, seedlings should be planted as soon as possible following harvesting.
- **Microsite selection:** Seedlings that are planted in the best microsite possible and that remain undamaged during the planting process are more likely to compete successfully with problematic vegetation.
- **Fertilization:** Fertilization treatments can potentially improve seedling establishment and reduce the need for brushing.
- **Advanced regeneration**: Another stand establishment option is to utilize advanced growth in the understory at the time of harvest. This could involve partial cuts such as shelterwood silviculture systems where silvics and site conditions are appropriate.

Pest identification

In the context of vegetation management, the term "pest" refers to herbaceous, shrub and broadleaf complexes or communities that:

- Inhibit plantation establishment;
- Hinder optimal growth and development of crop trees;

- Prevent a stand from achieving free growing;
- Affect an established plantation's overall health; or,
- When combined with snow, causes damage to crop trees by snow press.

Identification of potential vegetation problems starts with sound ecosystem classification from which vegetation complexes can be predicted. Post-harvest assessments and seedling monitoring can also help in identifying potential or realized brush problems.

Seedling and vegetation monitoring

Surveys and walkthroughs are scheduled throughout the plantations' development in order to ensure that stocking and brush levels are acceptable and that free growing parameters will be achieved within the appropriate time frame. Monitoring includes post-harvest assessments, regeneration delay surveys, regeneration performance walkthroughs, and free growing surveys.

Injury Thresholds and Treatment Decisions

Decisions to control vegetation on a site may be based on a number of different protocols depending on regional and ecological parameters. Measures such as competition index (CI) and height to diameter ratio (HDR) may be used to determine whether competing vegetation is negatively impacting crop trees. Crop tree status and vigour may also be evaluated based on local knowledge or % of crop trees that are overtopped, threatened, or above the brush.

Competition Index (CI) is a simple index that measures the competition for sunlight with regards to crop trees. CI is calculated as the sum of the products of cover and height for all non-crop species within a 1.26 meter radius around a crop tree, divided by crop-seedling height. CI shows that growth declines with increases in competition index. There is a very rapid decline in growth as CI increases from 0 to 100. At CI=100, growth is approximately 60% of that of a seedling growing free from competition. At a CI=150, seedlings receive 30% of the full sunlight in midsummer and would achieve approximately 45% of potential growth rates (Comeau et al., 1993). Treatment may be recommended when CI>80.

Height to diameter ratio (HDR) of crop trees can indicate sturdiness. In low light conditions, conifers will put more resources toward height growth, making them susceptible to vegetation and snow press. Treatment may be recommended with HDR>40 or 50, depending on species, where >50% of stems exceed the HDR.

Vegetation Management Options and Selection Criteria

Aerial Application

Broadcast treatment with a helicopter equipped with low-pressure boom and high-volume nozzles. Variable application rates are possible. May control brush for 2-4 years.

Discretionary, non-continuous application across portions of the block can also be applied.

The most cost-effective treatment and the safest option for workers on the ground

Benefits	Limitations
• Effective control for a number of years	• Less selective than other methods

- Minimal contact of chemical to workers
- Low cost
- Can treat remote, steep, slashy ground more safely than alternatives
- Can treat large areas in short time

- Stringent application constraints
- Intensive prep and follow up
- High public profile
- Residual leave trees are obstacles
- Visual quality affected for years
- Technically demanding
- Drift can occur outside treatment areas

Backpack Application

Backpack broadcast - continuous application across treatment unit with low-pressure backpack sprayer with adjustable nozzles. Variable application rates are possible. May control brush for 2-4 years. Discretionary non-continuous, or spot treatment can be applied.

Benefits

- Effective control for a number of years
- Can treat blocks with standing residuals
- Selective. Can apply with precision
- Only small buffers needed on Pesticide Free Zones

Limitations

- Stringent application constraints
- Intensive prep and follow up
- Requires high level of supervision
- Exposure of workers to herbicide
- Safety concerns wearing heavy equipment on rough terrain
- Access and water availability
- Constrained by brush height
- Inconsistent results from dew, rainfall and missed spots that are difficult to detect during monitoring.
- Safety concerns evacuating from remote sites
- Crew availability

Cut Stump

Selective application of herbicide onto a cut stump of target vegetation. Brush saw or power saw cuts stump and a worker applies herbicide using a backpack sprayer, squeeze bottle or nozzle mounted on the saw. May control brush for about 4 years.

Benefits

- Effective control for a number of years,
- Longer treatment window
- Little herbicide exposure to workers
- Only small buffers needed on Pesticide Free Zones
- Low application rate

Limitations

- Stringent application constraints prevents resprouting (lowest limb)
- Intensive prep and follow up
- Requires high level of supervision
- Exposure of workers to herbicide
- Safety hazards operating powersaws
- Safety concerns wearing heavy equipment on rough terrain

Motor Manual

Workers cut target vegetation with powersaws or brush saws. May control herbaceous brush for less

than a year, deciduous brush for about 2 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatment
• Public acceptance	• Safety hazards operating powersaws
• Can be applied selectively	• Expensive treatment cost
• Can be used in PFZ buffers	• Relative short window for treatment
• Not effective on herbaceous	• Limited availability of workers
	• Slash loads can be fire hazards, limit trafficability

Hand Tools

Workers treat spots around crop trees with handheld cutters.

Girdling hardwoods to remove a continuous strip bark around circumference which kills trees 2-3 years later.

Snap/hinge- partially breaking smaller stems by hand.

May control brush for less than a year. Girdling can control brush for about 3 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatment
• Public acceptance	• Expensive treatment cost
• Can be applied selectively	• Repetitive strain injuries are common
• Can be used in PFZ buffers	• Limited availability of workers
s.13	• Girdling not effective on herbaceous

Sheep Grazing

Shepherds guide a flock of sheep (1,000-1,500} through treatment areas where they eat target

vegetation. May control brush for a year.

Benefits	Limitations
• No herbicide use	• Expensive treatment cost
• Not constrained by weather	• Some crop tree damage
• Safe for workers	• Herbaceous, limited height
	• Need good access, gentle terrain, low slash, blocks in proximity
	• Risk of disease to wildlife

• Risk from predators

Mechanical Site Preparation

Mechanically creating favourable planting spots that mitigate limiting site factors such as cold, poorly

aerated soils, competing vegetation and frost risk. Where brush hazards are high, mounding is preferred so seedlings are elevated, receive more light and vegetation falls away from crop trees rather than pressing over them. Mounding is done with excavators or implements attached to prime movers such as skidders. May control brush for 3-5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Public acceptance	• Access and soil disturbance
• Increased soil temperature	• Site constraints- trafficability
• Facilitates planting	• Availability of contractors in the north

Prescribed Burning

Prescribed burning is another form of site preparation using ground crews or a helicopter to apply a

controlled burn. May control brush for 3-5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Good seedbed, plantable spots	• Liability and risk of escape
	• Smoke and health effects
	• Risks to workers

Treatment Selection

Treatment methods for a specific site will be selected based on a number of factors including safety concerns, timing, treatment efficacy, cost, biophysical constraints, legal constraints, political constraints and concerns from other users and stakeholders. Some of these factors include:

- **Target species height**: Backpack treatments cannot be sprayed overhead. Sheep are also constrained by their ability to reach foliage and are restricted to sites with vegetation of <1m in height.
- **Target species diameter**: Girdling becomes impractical at diameters of less than 3 cm or greater than 10 cm.
- **Target species distribution**: Broadcast foliar treatments are not effective if target species are in clumps. Discretionary treatments are less appropriate if the target brush is evenly distributed.

- **Physical impediments to treatment**: Aerial treatments can be limited by residual trees, or small, irregular shaped treatment units. Ground-based treatments can be affected by steep slopes, uneven terrain, slash loading, difficult access and remote access.
- **Buffers**: Blocks with many features that require No Treatment Zones and Pesticide Free Zones (PFZs), such as water bodies, wetlands, roads, etc, may have little treatable area for herbicide treatments once all the buffers are established.
- **Timing**: Chemical treatment windows are small and require conifers hardening off to avoid chemical damage while target species are still succulent. Motor manual treatment windows may overlap with fire season and are dependent on fire risk safety measures.
- **Special wildlife features**: Heavy browsing might reduce the need for brushing if there is little alternative browse available. Treatments that create heavy slash loads that restrict game movement may be avoided. Sheep grazing may be a poor choice in high grizzly bear use areas.
- **Vulnerable plant species**: Vulnerable plant species are defined as those plants whose numbers are either limited or are important for browse or forage. Vulnerable plant species must be protected from broadcast treatments where identified.
- **First Nations rights infringement**: When specific information indicates that there is a higher likelihood of treatments infringing on First Nations rights on a unit, certain treatments may be considered unsuitable, or modified. For example, if consultation with a First Nation produced indicated that a specific site is used for berry-picking, a broadcast chemical treatment would be considered inappropriate.
- **Potential for conflict**: Some proposed treatments may result in an unacceptable risk of conflict with the public, First Nations or other stakeholders.
- **Potential for crop tree damage**: Heavy slash loading from motor-manual treatments could mechanically damage crop trees. It can be hard to spot crop trees in dense vegetation which can result crop tree damage. Brushing can increase the risk of root rot spreading. Slash loading or dead stems can also create fire risks.
- **Availability of crews**: It is increasingly difficult to attract workers to the silviculture industry and brushing is onerous physical work. Safety is also a factor as higher numbers of injury claims are associated with higher claim payments for brushing and weeding. Fewer people are engaging in this sector (Dilkina 2019). The area manually brushed, 11,600 ha in 2018, would have to double to treat the sprayed area, so manpower availability would be limiting.

Post-treatment effectiveness evaluation

s.13

s.13

Environmental Protection Strategies and Procedures

s.13

(including herbicide transportation, storing, mixing, loading, disposal) and the environmental safeguards in place regarding herbicide field application, including:

- Strategies to protect community watersheds and other domestic water sources

- Strategies to protect fish and wildlife, riparian areas, and wildlife habitat
- Pesticide free zones (PFZ)
- Species at Risk
- Strategies to prevent herbicide treatment of food intended for human consumption
- Pre-treatment inspection procedures for identifying treatment area boundaries
- Weather monitoring and strategies
- Procedures for maintaining and calibrating herbicide application equipment

GLOSSARY

s.13

FLNRORD	BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FRPA	Forest Range and Practice Act
FSP	Forest Stewardship Plan
FPPR	Forest Planning and Practices Regulation

s.13

PMP	Pest Management Plan
PMRA	Health Canada Pest Management Regulatory Agency
RESULTS	Reporting Silviculture Updates and Land Status Tracking System

s.13



info@fpinnovations.ca
www.fpinnovations.ca

OUR OFFICES

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
(514) 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
(604) 224-3221

Québec
1055 rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
(418) 659-2647

BRIEFING NOTE FOR INFORMATION

DATE: November 21, 2019

PREPARED FOR: Diane Nicholls, Assistant Deputy Minister, Chief Forester, Minister of Forests, Lands, Natural Resource Operations and Rural Development

ISSUE: Summary of FPInnovations glyphosate review report

BACKGROUND:

- Glyphosate is a herbicide used by the forest sector to reduce broadleaf competition with conifer plantations in order to accelerate the attainment of free-to-grow status.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was awarded a $75,000[1] consulting services contract to assess current peer reviewed forest science and best practices related to glyphosate use in the context of, but not necessarily limited to:
    - The current value-set that applies to forest management throughout BC;
    - Where and why forest managers are still using glyphosate, how it relates to the current value-set (e.g., carbon, First Nations (FN), wildlife and wildlife habitat) and alternative vegetation management approaches;
    - Document the uncertainties and assumptions related to forestry-related glyphosate use; and
    - How glyphosate use supports the overarching objective of promoting the establishment of healthy and diverse forests.
- This note provides a summary of highlights, key findings and recommendations set out in FPI's report. Subsequent notes will address potential next steps, including internal and external communication.

HIGHLIGHTS, KEY FINDINGS AND RECOMMENDATIONS:

<u>General/Background</u>

- Glyphosate-based herbicides are the most widely used in the world due to their effectiveness and safety.
- The effects of glyphosate on human health have been extensively reviewed by international regulatory agencies, including Health Canada, with the conclusion generally being that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.

s.13

[1] Subsequently increased to $82,500.

Draft

s.13

Regulation and Use

- Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada. The PRMA re-approved glyphosate for use in Canada in 2017. After objections were raised regarding the re-approval the PRMA issued a supplementary statement in which it concluded that the objections could not be scientifically supported.
- The BC Ministry of Environment and Climate Change (ENV) regulates the sale and use of pesticides in BC under the Integrated Pest Management Act. Large scale use of pesticides requires the proponent to prepare and adhere to a Pest Management Plan.
- Notwithstanding its effectiveness as a silvicultural tool, glyphosate is also used to help manage invasive species. Of the 1,593 ha treated with herbicides for control of invasive species under the BC provincial jurisdictions of highways, forests and parks agencies, 8% of the area was treated using glyphosate.
- Data from this ministry's RESULTS shows that roughly 11,000 ha of Crown land was treated with glyphosate in 2018 with 86% sprayed aerially and 14% sprayed via ground-based methods. Most of the spraying of glyphosate occurred in the Omineca Natural Resource Region (73%) followed by the Northeast Region (11%). Smaller amounts of glyphosate use also occurred in the Thompson-Okanagan and South Coast Regions.
- In contrast to the agriculture and other common land uses where areas are sprayed repeatedly, glyphosate in forestry is typically applied once or occasionally twice in a rotation.
- Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species, but are most commonly used in the Sub-Boreal Spruce biogeoclimatic zone (targeting trembling aspen, mixed shrub, fireweed and wet alder).

Treatment Costs

- Glyphosate treatment costs vary widely, but are typically at least half that of manual methods (e.g., $300-$500/ha vs. $700-$1,200/ha). s.13

s.13

Biodiversity

- One of the primary public concerns regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broadleaves are being eliminated from the landscape. These claims are not supported when analysing the level of deciduous components at free-growing, or the increase in mixed deciduous stands over time as a result of forest management.
- A 2008 review of species diversity pre and post-harvest in BC found that the amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods. Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing, a 3,000% increase. Analysis further suggests that aspen stocking

recovers after glyphosate spraying and may in fact be increasing over time with forest management activities.

- Studies found that species richness and diversity of nontarget vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies also found that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment. In many cases, herbaceous vegetation abundance, diversity and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank. Further, while glyphosate tends to result in a larger initial reduction of a wider range of species, brushing alternatives such as manual brushing has similar effects on plant communities, albeit at a higher treatment cost.
- Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least 1 year. Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality, however some translocation into shoots and fruit was observed in select plants.

Aquatic Organisms

- Amphibian populations are declining around the world and chemical contaminants released to aquatic environments have been listed as a threat. Studies have shown direct effects of chronic glyphosate exposures on fish, amphibians, invertebrates and other components of the ecosystem. However, field studies have not been able to replicate these toxicity effects under typical glyphosate application rates and conditions. Further, numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development, the expression of genes related to larval development, or juvenile amphibian survival. This is likely due to the short exposure duration and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands.
- A field study in coastal BC found temporary stress effects and minor mortality in caged Coho salmon smolt post glyphosate application. However, no acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident Coho. Similarly, no effects on growth, behaviour or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment. While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations in BC mandate the use of no-treatment pesticide-free zones around water features, dry streams and classified wetlands, further reducing the risk of negative effects on aquatic ecosystems.

Wildlife

- Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates. However, some uncertainty remains regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage.
- Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline.
- Glyphosate treatment has been found to reduce wildlife forage availability in the short term, reducing moose use of glyphosate-treated area for the first few years after treatment. However, the long-term impact of glyphosate use on habitat selection by moose is not well

understood. Further, some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls although these impacts must also be considered in relation to the area treated annually and its distribution over the landscape. The effects of glyphosate's chelating properties on forage quality and nutrient availability are also poorly understood.

Soil and Water Quality

- Glyphosate is largely immobilized in the soil and then dissipates via microbial degradation. One of the compounds released during the microbial breakdown process – AMPA – is adsorbed to soils and biodegraded. However, AMPA is considered to be a mild phytotoxin with relatively unknown long-term consequences on soil organisms and plants.
- The mandated use of no-treatment pesticide-free zones around water features, the strong sorption to upper soil layers and the rapid uptake by plants minimize the risk of glyphosate entering aquatic ecosystems. Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken.

Climate Change

- Vegetation management can affect carbon sequestration due to its impact on structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows the establishment of a woody crop delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools. When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species.

Wildfire

- Fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires.
- The Canadian Forest Fire Behaviour Prediction system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous or leaf-on mixed wood stands.
- Amongst deciduous trees, poplars show the most fire resistance. In one study, researchers estimate broadleaf forests to remain next to inflammable even as drought conditions worsen, in stark contrast to coniferous forests.
- The effect of fire behaviour from deciduous vegetation treated with glyphosate is not well documented. It is expected that the fire hazard in treated dead stems following treatment either manually or chemically would be very high.

First Nations

- Some First Nations across BC have expressed concern over the use of glyphosate in forests related to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated.

s.13

Public Use

- Forest managers are faced with mounting public pressure over the safety of glyphosate use.
- Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry

Draft

picking, mushroom picking, firewood cutting, camping or hiking. The Canada Pest Management Regulatory Agency's review on glyphosate has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health.

- There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues.
- Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue.
- Better communication of the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, between forest managers and recreational users can help address key public concerns.

s.13

Timber Supply

- Vegetation control in some cases is necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests.
- Glyphosate is cost-effective vs. manual vegetation control methods.
- Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked area with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

Conclusions

s.13

- A review of current inventory data shows that stands that have been treated with glyphosate retain 15-21% deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.
- Field studies have shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.
- Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.
- While more research is recommended on the identified knowledge gaps, the use of glyphosate needs to be further considered within the context of the amount of area treated, the short time

scale of site-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels. Many of the public's concerns and challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by better linkages between site and landscape level planning that allow other non-timber values to be prioritized where needed.

Recommendations

s.13

Attachments: FPI Report – Review of Glyphosate Use in BC Forestry (Nov. 2019)

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
ADM		
ED		
Program Dir/Mgr.		

Begon, Stacey FLNR:EX

From: Hedges, Shawn FLNR:EX
Sent: November 21, 2019 10:59 AM
To: Berg, Shane FLNR:EX; Zacharias-Homer, Christa ENV:EX; MacDougall, Julie FLNR:EX; Psyllakis, Jennifer FLNR:EX; Mullan, Jonathan M ENV:EX; Bedford, Lorne FLNR:EX; Hughes, Neil FLNR:EX; Gordon, Steve M FLNR:EX
Cc: van den Broek, Jude FLNR:EX
Subject: Draft BN re: summary of FPI glyphosate report
Attachments: 12345 - ADM IN - Summary of glyphosate review report (Nov 21_19).docx

Colleagues, attached is a longish first draft of summary BN I've written for our Chief Forester re: FPI's glyphosate report. I don't have the final report in-hand yet and so have used the Nov 6 FPI draft we jointly reviewed as the basis for the BN.

Note that my intent to update this BN if/as required once I have the final report in-hand and then move it along to Diane. In the meantime, if you have any comments or concerns I'm all ears.

Ps. My intent is to eventually prepare a much shorter version of the BN before my Christmas break for the minister, deputy and select ADMs which will also set out the go-forward plan that we need to discuss and land as a team. I'll book a call shortly.

_____

Shawn Hedges, RPF
Director, Sustainability & Forestry
Office of the Chief Forester
Forests, Lands, Natural Resource Operations & Rural Development
Cellular (250) 896-9911

FPInnovations

info@fpinnovations.ca
www.fpinnovations.ca

REVIEW OF GLYPHOSATE USE IN BC FORESTRY

BRITISH COLUMBIA

Jim Hunt, Lead Scientist

Pamela Matute, Researcher

FPInnovations

Current glyphosate use in BC forestry was reviewed including peer-reviewed forest science on the impacts of glyphosate use on forests as well as input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishment of forest stands post-harvest.

Project number: 301013763

ACKNOWLEDGEMENTS

This project was contracted by the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

APPROVER CONTACT INFORMATION
Shawn Hedges
Director, Sustainability and Forestry

shawn.hedges@gov.bc.ca

REVIEWERS
Ken Byrne, Manager, Fibre Supply

AUTHOR CONTACT INFORMATION
Jim Hunt
Lead Scientist, Fibre Supply
james.hunt@fpinnovations.ca
(604) 222-5618

Disclaimer to any person or entity as to the accuracy, correctness, or completeness of the information, data, or any analysis thereof contained in this report, or any other recommendation, representation, or warranty whatsoever concerning this report.

Follow us

Table of contents

Executive Summary 1
1 Introduction 3
2 Use of Glyphosate in BC Forests 4
2.1 Regulatory Framework 4
2.1.1 Free Growing 4
2.1.2 Herbicides 5
2.2 Why is Glyphosate Used? 6
2.2.1 Site Preparation 7
2.2.2 Plantation Survival 7
2.2.3 Crop Tree Productivity 7
2.2.4 Invasive Species 7
2.3 How is glyphosate used? 8
2.3.1 Area treated 8
2.3.2 Glyphosate Use at the Stand-Level 12
2.4 Treatment Costs 14
3 Impact of glyphosate use on non-timber values 15
3.1 Biodiversity 15
3.1.1 Broadleaf Tree Species 15
3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide 15
3.1.1.2 RESULTS Analyses 16
3.1.2 Non-Target Plant Communities 18
3.1.3 Aquatic Organisms 19
3.1.4 Wildlife 20
3.1.4.1 Toxicity 20
3.1.4.1 Forage quality and quantity 21
3.2 Soil and Water Quality 21
3.2.1 Glyphosate/AMPA fate in soils 21
3.2.2 Soil micro-organisms 22
3.2.3 Glyphosate/AMPA fate in water 22
3.3 Climate Change 23

3.4 Wildfire 24
3.5 First Nations 24
3.6 Public Use 25
4 Impacts on Timber Supply 26
4.1 s.13 27
5 Recommendations 28
6 Conclusions 29
6 References 31
Appendix 1. International Assessments 43
Appendix 2. Stocking Standards and Survey Changes Related to Deciduous Management in BC 46
Appendix 3. Integrated Pest Management Principles 47
Glossary 54

EXECUTIVE SUMMARY

FPInnovations was contracted by the Office of the Chief Forester to undertake a review of current glyphosate use in BC forestry including peer-reviewed forest science on the impacts of glyphosate use on forests as well as input from stakeholders. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered. This report focuses on the silvicultural application of glyphosate as a vegetation management tool in re-establishment of forest stands post-harvest. The report will inform future policy development and research needs with the main objective to promote the establishment of healthy and diverse forests.

The herbicide glyphosate is one of many vegetation management tools available to forest managers. As a tool for vegetation control, it is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. It is very effective because it is easily translocated within the target plant, usually killing it and reducing the brush hazard for multiple years after a single application, unlike other motor-manual vegetation control methods. Glyphosate application may target aggressive competition from broadleaved trees, shrubs and herbaceous vegetation.

Roughly 11,000 ha of crown land were treated with glyphosate in BC for silviculture in 2018. Total area treated with glyphosate was 7% of the area harvested in 2018 on BC crown land, and less than 0.5% of the area with outstanding reforestation obligations. In 2018, most (73%) of the glyphosate application occurred in the Omineca Natural Resource Region. Of all biogeoclimatic zones, the Sub-Boreal Spruce zone saw the most glyphosate use (76%). Glyphosate was primarily applied aerially (86%) while the remainder 14% was treated using ground-based methods.

Public concerns over the impacts of glyphosate use on the ecosystem is currently growing, particularly regarding ecosystem changes resulting from the control of broadleaf trees such as trembling aspen. A RESULTS (Reporting Silviculture Updates and Land Status Tracking System) analysis of deciduous stand components at free growing showed that in the Omineca, where most of the glyphosate application takes place, deciduous components accounted for 15-21% of the stand density in sites that were previously treated with glyphosate. Data also shows that in the BC interior, mixed deciduous stands have been increasing over time as a result of forest management activities.

A summary of the many studies regarding the impact of glyphosate on forest soils, water, non-target plant communities, and wildlife is presented. While impacts can vary with site characteristics, research has shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes to these communities are related to changes in vegetation structure and are transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. Recent research has found low but unexpected levels of glyphosate residue in plants one year following treatment, which may have implications on wildlife forage quality, plant physiology and traditional food and

medicine plant harvesting. While residue levels were non-toxic to humans and wildlife, little is known about their effect on forage quality and the impact, if any, of chronic low-level exposure on wildlife that relies on this forage, such as moose.

Glyphosate remains an important tool for establishing conifer or conifer-deciduous mixed stands and ensuring future timber supply. Glyphosate bans in other jurisdictions in Canada have resulted in significant struggles to meet timber objectives in the land base, highlighting glyphosate's important role in maintaining conifer productivity. Forest management in BC seeks to balance all values ascribed to the forest with the overarching objective of establishing and maintaining healthy and diverse forests. While more research is recommended on the identified knowledge gaps, glyphosate needs to be considered in the context of these values and objectives, and with perspective regarding the amount of area treated, the apparent transient effects on the site's ecology, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels.

1 INTRODUCTION

Public pressure to reduce the use of glyphosate has been increasing in British Columbia and other jurisdictions. In response, the Office of the Chief Forester for BC Ministry of Forests Lands, Natural Resource Operations and Rural Development's (FLNRORD) ~~of BC~~ contracted FPInnovations to undertake a review of current peer-reviewed forest science and best practices on glyphosate use in the BC forestry. Input from stakeholders was also solicited. The use of glyphosate in relation to the multiple values pertinent to forest management in BC was considered[1]. The report will inform future policy development and research needs with the main objective to promote the establishment of healthy and diverse forests. s.13

s.13

Formatted: Not Highlight

s.13

Successful regeneration of forests after timber harvesting often requires control of competing vegetation which may cause mortality or reduced growth of established seedlings. Several vegetation management alternatives exist for this purpose, including s.13

s.13

s.13

Glyphosate-based herbicides are the most widely used in the world, largely due to their effectiveness, their safety for non-target species and the environment, and the development of glyphosate tolerant agricultural crops (Edge et al., 2014). Several factors support the use of this herbicide in forestry applications in BC:

- Ability to translocate within treated plants and control resprouting of perennial weeds;
- Generally favourable environmental profile, including binding in soils and rapid biodegradation in most soils, water and sediments;
- Specific mechanism of action, inhibiting an enzyme found only in plants;
- Low toxicity to animals; and
- Minimal impact on forest ecosystems (Rolando et al., 2017).

s.13

1 See Forest Planning and Practices Regulation Part 2, Division 1.

2 USE OF GLYPHOSATE IN BC FORESTS

2.1 Regulatory Framework

2.1.1 Free Growing

In BC, timber harvesting in public forests is regulated such that any harvested area must be reforested to an acceptable standard of free growing. The *Forest Range and Practices Act*[2] (FRPA) (sec 1) defines "free growing" as "*a stand of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees*". A free growing stand is expected to contribute to landscape objectives and to a sustainable long-term fibre supply.

Formatted: Font: Italic

The Forest Planning and Practice Regulation~~3~~ (FPPR) (Sec 44) addresses obligations to produce a free growing stand that meets applicable stocking standards approved in a Forest Stewardship Plan (FSP) by specified dates. Stocking standards are regulatory tools that ensure that the re-establishment of a forest stand post-harvest is aligned to large-scale objectives for the land base as set out in FSPs. Stocking standards specify regeneration requirements such as suitable tree species for the site, stand density, spacing, free growing height and ratio of crop tree height to surrounding competing vegetation.

Sec 46.11 of the FPPR indicates that these silvicultural obligations must be fulfilled on each hectare within the net area to be reforested, unless otherwise specified in an FSP. Mappable areas that do not meet stocking standards should not exceed 2 ha or 5% of the Standard Unit (SU) area. Under FPPR section 97.1, an obligation holder may be relieved of the obligation to meet stocking standards if they can prove that obligations have been met to the extent that is practicable.

Sec 26 (5) of the FPPR ~~Sec 26 (5)~~ also provides a mechanism to develop stocking standards in an FSP that are not consistent with current timber supply assumptions. The review test for sec~~tion~~ 26 (5) requires the Delegated Decision Maker to be satisfied that the regeneration date and stocking standards are reasonable, having regard for future timber supply and the set values ascribed to forest land.

Free growing surveys are the tool by which forest managers measure whether a stand meets free growing obligations. Survey methods, including quantification of shrub and broadleaf competition, are described in the Silviculture Surveys Procedures Manual[4]

Stocking standards and related guidance have evolved since the 1990s and continues to evolve to incorporate current understanding of resource issues (e.g. broadleaf species) and their

2 http://www.bclaws.ca/Recon/document/ID/freeside/00_02069_01

~~3 http://www.bclaws.ca/civix/document/id/lc/statreg/14_2004~~

4 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

impact on timber supply and other forest values. A summary of these developments is described in Appendix 2.

2.1.2 Herbicides

Health Canada's Pest Management Regulatory Agency (PMRA)[5] is responsible for regulating pesticide use in Canada to ensure they pose minimal risk to human health and the environment. Under authority of the Pest Control Products Act, Health Canada:

- registers pesticides after a stringent, science-based evaluation that ensures any risks are acceptable;
- re-evaluates the pesticides currently on the market on a 15-year cycle to ensure the products meet current scientific standards; and
- promotes sustainable pest management.

s.13

s.13

The *Integrated Pest Management Act* (IPMA) and Regulation[6] (IPMR) sets out the requirements for the use and sale of pesticides in BC[7]. The BC Ministry of the Environment and Climate Change Strategy (ENV) promotes Integrated Pest Management (IPM) and environmental stewardship and ensures compliance with the IPM Act and Regulations. Large scale pesticide programs (i.e. >20 ha/year of treatment area) that require IPM must have a confirmed Pest Management Plan (PMP). PMPs document how the standards set in the IPMR will be implemented regarding

Formatted: Font: Italic

s.13

s.13

IPM is a process for managing pest populations. In a forestry context where competing vegetation is considered as a pest or weed, the following integrated vegetation management elements would apply:

- Planning and managing ecosystems to prevent organisms from becoming weeds;
- Identifying weed problems and potential weed problems;
- Monitoring populations of weeds and weed complexes;
- Using injury thresholds[8] in making treatment decisions;
- Select pest treatment methods based on:

5 https://www.canada.ca/en/health-canada/corporate/about-health-canada/branches-agencies/pest-management-regulatory-agency.html

6 https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management/pesticide-use/regulations-consultations

7 https://www2.gov.bc.ca/assets/gov/environment/pesticides-and-pest-management/business-and-industry/forestry_review.pdf

[8] The injury threshold is the level at which pest numbers are high enough to cause unacceptable injury or damage.

- Consideration of practical alternatives to herbicide use,
- Protection of human health and the environment; and

- Evaluating the effectiveness of weed management treatments.

Herbicides are rarely the only integrated vegetation management method used and are generally used in conjunction with other methods. Examples of best practices for implementing integrated vegetation management are included in Appendix 3.

2.2 Why is Glyphosate Used?

Managing competing vegetation is an essential part of reforestation efforts after forest harvesting. In B.C., vegetation management focuses on highly aggressive herbaceous complexes such as fireweed or bluejoint grass, and competitive deciduous trees such as red alder, broadleaf maple and trembling aspen. Targeted vegetation control is used for two main reasons in silviculture:

Commented [MOU9]: Used as "BC" (not "B.C.") elsewhere

- to maintain plantation survival, and
- to meet free growing obligations that ensure stand productivity and sustainable future timber supply.

s.13

Depending on the developmental stage of a plantation and its brush complex, glyphosate may be used to: clear a planting site of pre-established brush, to reduce seedling competition in order to ensure plantation survival, or to meet free-growing requirements that ensure long-term productivity and timber supply, particularly where specific timber species and outcomes are being managed for.

2.2.1 Site Preparation

s.13

2.2.2 Plantation Survival

Plantations on sites with aggressive competing vegetation complexes can fail within a year without effective vegetation management. In these cases, interventions are often needed to avoid excessive seedling mortality and plantation failure (Comeau and Harper, 2009; Biring et al., 2003; Comeau et al., 1999). This application of glyphosate is particularly important with herbaceous vegetation complexes for which mechanical cutting is not effective, such as bluejoint reed grass (*Calamagrostis canadensis*). Bluejoint reed grass is a serious competitor in northeastern BC, where it often colonizes sites after harvest forming thick colonies that can prevent establishment of shrub and tree species for upwards of 25 years if left uncontrolled (Dunbar et al., 2011). Glyphosate application on these sites can suppress the growth of competitive vegetation ~~for~~ enabling tree seedlings to become established.

2.2.3 Crop Tree Productivity

s.13

s.13 A single application of glyphosate during the first few years after planting in high-brush sites has been shown to effectively improve conifer growth 9 to 20 years later in a wide range of plant communities in various ecosystems in ~~British Columbia~~BC (Harper et al., 1997a, b; Whitehead and Harper 1998; Biring et al., 1999, s.13 Biring and Hays-Byl 2000; Simard 2001; Harper et al., 2005; Boateng et al., 2006; Macadam and Kabzems 2006). There is substantial variation in the magnitude of reported growth gains as they are dependent on type, intensity and duration of vegetation competition; in certain cases, the effects have been found to be significant but can also be short-term (Comeau et al., 1999; Heineman et al., 2005; Comeau and Harper, 2009).

Commented [MOU12]: ?

2.2.4 Invasive Species

While the focus of this report is on use of glyphosate in BC silviculture, glyphosate may also be used in forests to control the spread of noxious and invasive weeds across the province. FRPA sec 47 indicates that a person carrying out a forest or range practice must carry out measures to prevent the introduction or spread of prescribed species of invasive plants as listed in the invasive species regulation. The BC Weed Control Act requires all land occupiers to control the spread of noxious weeds on their land or premises.

s.13

s.13

2.3 How is glyphosate used?

2.3.1 Area treated

Data from the RESULTS s.13 database s.13

s.13

s.13

o FPInnovations shows that roughly 11,000 ha of crown land were treated with glyphosate for silviculture in 2018[11] with 86% sprayed aerially and 14% sprayed using ground-based methods (Figure 1). Aerial, ground-based and alternative methods are discussed in Appendix 3. The area sprayed has declined from an average of 13,802 ha for the last five years and higher historical levels. The area sprayed in 2018 was 0.044% of the 25 M ha available for harvesting in BC and 0.44% of the tenured area on crown land that has an outstanding reforestation obligation.

s.13

9 https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/invasive-species/pest-management/2019_herbicide_summary_for_control_of_knotweeds_on_crown_lands.pdf

10 https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-reporting-results

11 This includes aerial and ground-based brushing and site preparation treatments excluding 'basal spray' and 'stem bark spray' silviculture methods which do not apply to glyphosate. It may include some triclopyr application that was reported as Backpack treatment method. Private land is not included.

s.13

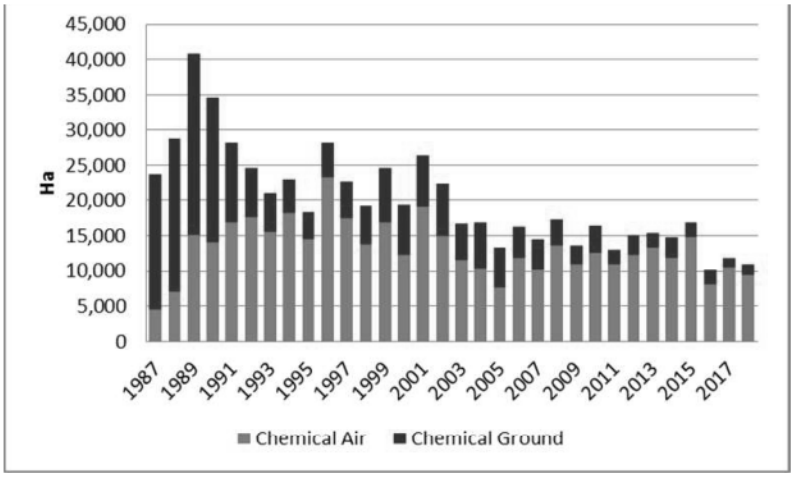


Figure 1. Area sprayed with glyphosate for silviculture in BC.

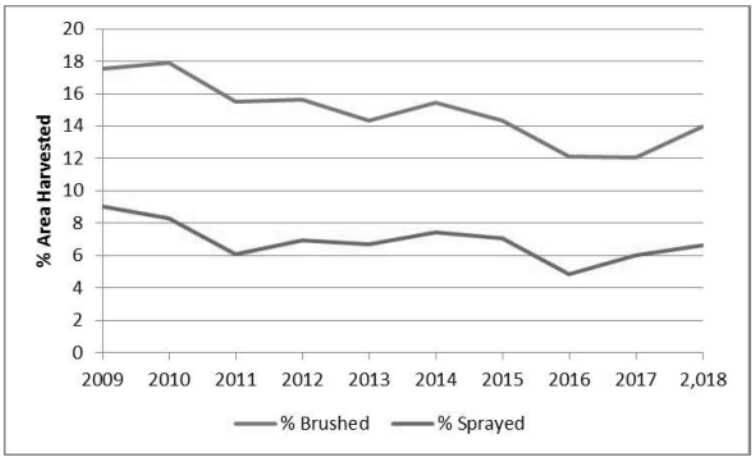


Figure 2. The percentage of harvested area that is brushed with alternative methods and sprayed with glyphosate.

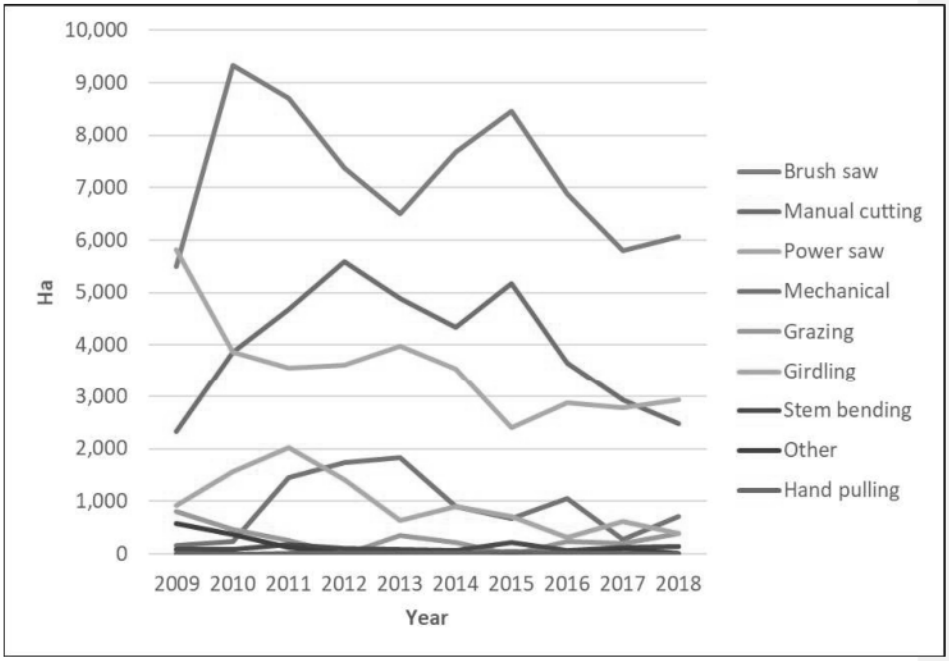


Figure 3. Area brushed with non-chemical methods.

Most of the spraying occurred in the Omineca Natural Resource Region (73%) followed by the Northeast Region (11%) (Table 1). The Prince George Timber Supply Area (TSA) comprised 68% of the total provincial area sprayed with glyphosate in 2018. Aerial applications made up 96% of the spray programs in those Regions. Small aerial programs also occurred in Thompson-Okanagan and South Coast Regions. Small ground-based programs occur in all regions with the largest occurring in the South Coast Region. The proportions of area harvested that were sprayed with glyphosate range from 11-15% for the South Coast, Northeast and Omineca regions, while the remaining regions in the province were less than 3% of the harvested area (Table 1).

Table 1. Area sprayed with glyphosate by Natural Resource Region (ha) in 2018.

s.13

The biogeoclimatic (BGC) zones (Meidinger and Pojar 1991) where most of the glyphosate application occurred are the Sub-Boreal Spruce (76%) and Boreal White and Black Spruce (9%) zones (Table 2). s.13 . The drier SBS subzones (dry warm (dw) and moist cool (mk)) are dominated by aspen while the wetter subzones (wet cool (wk) and very wet cool (vk)) are dominated by herbaceous vegetation.

Table 2. Area sprayed with glyphosate by BGC zone (ha) in 2018

s.13

s.13

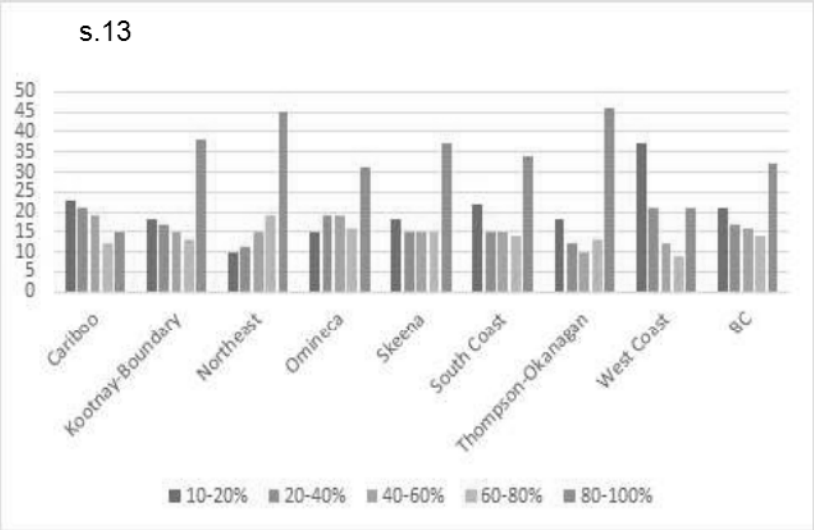
2.3.2 Glyphosate Use at the Stand-Level

Glyphosate is generally used in a targeted portion of the total reforestation area, as opposed to covering entire cutovers.s.13

s.13

[12] This analysis included blocks that were treated with herbicide one time only

s.13



s.13

In contrast with agriculture and other common land uses where areas are sprayed repeatedly,

s.13

s.13 The percentage of blocks treated more than twice was 32% for ground-based and 11% for aerial in BC. The Coast regions had a higher proportion of retreatments s.13

s.13

s.13

	Ground			Aerial		
	Number of Treatments					
	1	2	>2	1	2	>2
	%			%		
Cariboo	74	20	6	83	16	1
Kootenay	44	42	14	100	0	0
Northeast	64	25	12	53	30	17
Omineca	89	10	1	68	24	8
Skeena	79	11	10	70	15	15
South Coast	41	29	30	79	21	0
Thompson	75	17	8	45	33	22
West Coast	24	19	58	63	25	11
BC	47	21	32	65	25	11

Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species. Commonly targeted vegetation complexes in the SBS, where most of the glyphosate application takes place, are trembling aspen, mixed shrub, fireweed and wet alder. The BWBS zone is dominated by aspen/poplar and reed grass complexes (Comeau et al., 1996).

Target species are indicated on brushing prescriptions developed from operational surveys. A licensee in the Prince George region has indicated that 53% of the 2018 aerial spray area targeted aspen while 47% targeted herbaceous/shrub competition. Aggregated data of which complexes are targeted the most by glyphosate application is currently lacking. More work is required to understand how glyphosate use is distributed amongst particular vegetation complexes or species to understand how and why glyphosate is used, and what the impact of not using glyphosate would be.

2.4 Treatment Costs

Treatment costs vary considerably depending on location, access, treatment intensity, availability of crews and equipment, logistics, etc. BCTS and ~~Licensees~~ licensees reported that manual treatments ($700-$1,200/ha) are twice the cost of glyphosate treatments ($300-$500/ha) and require at least two treatments. The cost of achieving free growing on a site that needs vegetation control ranges from $900-$2,100/ha more when using manual treatments. An example of treatment costs to attain free growing with and without glyphosate in the Prince George region was provided by BCTS (s.13 Assuming the s.13 example is representative and applying an average cost difference of $1,400/ha to the 11,000 ha area that was sprayed in 2018, the cost of not using glyphosate for silviculture is estimated at $15.4 M per year.

s.13

s.13

s.13 costs are an important consideration - safety, access, crew availability, treatment windows and various operational factors also affect the selection of treatment options discussed in Appendix 3.

3 IMPACT OF GLYPHOSATE USE ON NON-TIMBER VALUES

s.13

3.1 Biodiversity

The FPPR indicates the objective set by the BC government for wildlife and biodiversity at the landscape level is, without unduly reducing the supply of timber from British Columbia's forests and to the extent practicable, to design areas on which timber harvesting is to be carried out that resemble, both spatially and temporally, the patterns of natural disturbance that occur within the landscape.

3.1.1 Broadleaf Tree Species

Mixedwood forests provide various ecological, social, and non-timber values; have significant value in shaping forest ecology, stand structure, and function; and exert a strong influence on forest diversity and resilience (Harper 2014).s.13

s.13

3.1.1.1 Aspen regeneration post-harvest and persistence after herbicide

On sites where it exists pre-harvest, aspen regenerates aggressively from suckering after a stand-replacing event such as fire or harvesting (Frey et al., 2003). This is particularly the case in the boreal and sub-boreal mixedwoods that make up large portions of Central and Northeastern BC, where research has shown that in order to establish a conifer crop, vegetation management is often required to counter the suckering of aspen following harvest (Wood and von Althen 1993; Cole et al., 2003; Pitt and Bell 2005; Boateng et al., 2006).

s.13

While those studies focused on deciduous composition within herbicide-treated areas, it's important to note that glyphosate is not generally applied to entire harvest units (see section 2.3.2), and that the total elimination of competitive vegetation is not a silvicultural objective of

conifer-release programs (Bell and Newmaster 2002). In B.C., vegetation management treatments, including glyphosate application, are carried out only in the portions of a harvest unit where they are deemed necessary for conifer survival or to meet free-growing stocking standards in each standard unit as per Sec 46.11 of the FPPR.

3.1.1.2 RESULTS Analyses

A 2008 Forest and Range Evaluation Program (FREP) review of species diversity pre- and post-harvest in B.C. found that the amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods (BCMFLNROR 2008). Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing, a 3,000% increase.

Commented [MOU23]: Did you mean to say FLNRORD?

An up-to-date RESULTS query of stand composition for all stands declared free growing following herbicide treatment (aerial and ground-based) was prepared for this report by FLNRORD.s.13
s.13

This corresponds to 15% and 16% broadleaf components (by stem density).

In the Northeast and Omineca Regions, where most herbicide treatments take place, the average number of deciduous stems/ha at free growing following aerial herbicide treatments were 864 and 445 stems/ha, or 27% and 15% of the total stand species composition s.13
s.13

In general, ground-based application resulted in a slightly higher number and percentage of deciduous stems at free growing compared with aerial application for most regions.s.13
s.13

s.13

s.13

s.13

3.1.2 Non-Target Plant Communities

3.1.2.1 Diversity of plant communities

A review of 12 studies by Sullivan and Sullivan (2003) found that species richness and diversity of nontarget vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies report that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment (Sullivan et al., 1998a, Freedman et al., 1993; Lautenschlager and Sullivan 2002, Bell and Newmaster 1998; Hawkins et al., 2013; Comeau and Fraser, 2018). In many cases, herbaceous vegetation abundance, diversity and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank (Sullivan and Sullivan, 2003; Kabzems and Harper, 2015).

While broadcast aerial spraying of glyphosate is sometimes seen as a blunt vegetation management tool, studies have found that it doesn't target all vegetation equally. On sites with a vertical vegetation structure (comprised of aspen, shrubs, and forbs), one study found that the majority of the spray was deposited in the aspen canopy (68% of the nominal application rate), while shrubs and herbs captured approximately 25% and 12% of the nominal application rate, which may further help explain their quick recovery (Thomson et al., 1997).

Only two of the twelve studies analyzed by Sullivan and Sullivan (2003) observed an overall reduction in species richness of shrubs after glyphosate application (Santillo et al., 1989a; Sullivan et al., 1988). Santillo et al. (1989) found that species richness was decreased by 50% and

Commented [MOU24]: ?

30% for shrubs and herbs respectively one year after treatment and continued to be lower in the treatment units after three years. The control sites in this study however were at a different successional stage than the glyphosate treatment units (Santillo et al., 1989a). Sullivan et al. (1988) likewise observed a reduction in shrub species richness 5 years after treatment.

s.13

3.1.2.1 Persistence of glyphosate/AMPA in plant tissue

Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions (Gomes et al., 2014) due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels s.13 s.13 in some surviving perennial forest plants for at least 1 year (Wood 2019). Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality, however some translocation into shoots and fruit was observed in select plants (Wood 2019).s.13 s.13

s.13

s.13

3.1.3 Aquatic Organisms

Amphibian populations are declining around the world (Houlahan et ~~at~~ al., 2000), and chemical contaminants released to aquatic environments have been listed as the second most important threat to amphibians after habitat loss (Edge et ~~at~~ al., 2011).s.13 s.13

s.13

Numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development (Edge et al., 2012, Lanctot et al., 2013, Edge et al., 2014b), the expression of genes related to larval development (Lanctot et al., 2013), or juvenile amphibian survival (Edge et al., 2011, 2013). This is likely due to the short (but environmentally realistic and relevant) exposure duration (generally less than 96 hours) and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands (Edge et al., 2012, 2014b, Baker et al., 2016).

A watershed level study in coastal BC found temporary stress effects and minor mortality (2.6%) in caged coho salmon smolt in an experimentally over-sprayed tributary and the main stream below the sprayed area immediately post glyphosate application. No acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident coho (Legris and Couture, 1991; Feng et al., 1990; Reynolds et al., 1993). Similarly, no effects on

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: Not Highlight

Formatted: Not Highlight

growth, behaviour or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment (Morgan and Kiceniuk, 1992).

s.13

3.1.4 Wildlife

3.1.4.1 Toxicity

Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates (Durkin et al., 2003; Giesy et al., 2000; PMRA, 2015). Some uncertainty remains in the literature regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage. While observed residue levels were non-toxic to mammals, the effects of chronic sub-lethal exposure to mammals are not yet well-understood and require more research (Wood, 2019; Mesnage et al., 2015; Kissane and Sheppard, 2017)

Effects on terrestrial wildlife communities, like in aquatic ecosystems, are primarily linked to the changes in vegetation cover and forage quality. As such, species responses are highly variable and reflect individual habitat preferences. Studies on wildlife response to habitat alteration from glyphosate application have shown no effect, short-term negative effects and positive effects on different wildlife species (Guynn et al., 2004). All in all, studies suggest that species richness and diversity of small and large mammals s.13 songbirds and invertebrates remain within the range of natural variation and that changes are transient (Sullivan and Sullivan 2003).

3.1.4.1 Forage quality and quantity

Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline (Kuzyk et al., 2018).

s.13

s.13 The long-term impact of glyphosate use on habitat selection by moose is not well understood however. Biring et al. (1999) reported decreased forage abundance and use 12 years after glyphosate application in a BWBS site. However, Newton reported a 46% decrease in forage the year following glyphosate application, but a 660% increase in forage at year 8 compared to the control (Newton et al., 1989), and some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls (Raymond et al., 1996; Eschholz et al., 1996). These impacts must also be considered in relation to the area treated annually and its distribution over the landscape (Lautenschlager and Sullivan 2002).

The effects of glyphosate's chelating properties on forage quality and nutrient availability are poorly understood. s.13 properties of glyphosate allow it to bind macro- and micronutrients (in particular iron, manganese, zinc, copper and nickel) which can s.13 impact uptake and availability in plants treated with glyphosate (Mertens et al., 2018). These micronutrients are particularly important to ungulates such as moose, whose sensitivities to mineral imbalances (in particular Cu) have been implicated in moose population decreases in Alaska, Sweden and Minnesota (Custer et al., 2004; Flynn et al., 1977; O'Hara et al., 2001; Frank et al., 1994).

Studies on nutrient uptake by surviving plants in agricultural settings after glyphosate application has provided contradictory accounts (Gomes et al., 2014), in some cases a reduced uptake of micronutrients by plants has been found (Eker et al., 2006; Tesfamariam et al., 2009; Cakmak et al., 2009). While in others (Duke et al., 2012; Duke et al., 2018) no effect on micronutrient content was found. More research is required on whether glyphosate application leads to a reduced micronutrient content specifically in wildlife forage, and whether this is implicated in the population declines of moose in BC.

3.2 Soil and Water Quality

3.2.1 Glyphosate/AMPA fate in soils

After application, glyphosate is largely immobilized in the soil due to its strong sorption characteristics that allow it to bind with soil particles and organic materials. Once glyphosate reaches the soil, the main pathway for glyphosate dissipation in soil is microbial degradation, as many species of soil microorganisms can use glyphosate as their soil carbon source (Durkin, 2003). One of the main compounds released during the microbial breakdown process, ~~aminomethylphosphonic acid (~~AMPA~~)~~, is likewise adsorbed to soils and biodegraded, yet considered to be a mild phytotoxin (Reddy et al., 2004; Gomes et al., 2014) with relatively unknown long-term consequences on soil organisms and plants.

Commented [MOU31]: Acronym previously defined.

Sorption and degradation processes are highly dependent on microbial activity and soil composition (Székács and Darvas, 2012). The rate of sorption and degradation of both glyphosate and AMPA vary greatly in agricultural applications, with half-lives ranging between a few days to several months, and even up to a year (Székács and Darvas, 2012). While it has been argued that the short growing season in northern climates may restrict degradation, North American studies in forest applications have found that the time for 50% dissipation (DT50) in litter and soil is 8 to 19 days, and 5 to 40 days respectively (Newton et al., 1984; Newton et al., 1994; Thompson et al., 2000; Feng and Thompson, 1990; Hagner et al., 2019).

3.2.2 Soil micro-organisms

Soil organisms play a crucial role in nutrient cycling and maintaining ecosystem productivity. Research on the effect of glyphosate in micro-organisms in laboratory studies has been contradictory. Laboratory studies have found exposure to glyphosate formulations may either decrease (Druille et al., 2013; Zaller et al., 2014; Tanney and Hutchinson, 2010; Estok et al., 1989; Sanogo et al., 2000; Diaz et al., 2003) or rarely stimulate (Laatikainen and Heinonen-Tanski 2002; Diaz et al., 2003) proliferation of certain fungal species. Laboratory studies on cultured microorganisms are likely to overestimate toxicity effects (Estok et al., 1989), however. Field studies of the effect of glyphosate application on forest soil organisms and microbial processes are limited and their findings often contradictory. Some detrimental effects on fungal communities and nutrient cycling have been documented by Munson et al. (1993) and Vitousek et al. (1992). Similarly, annual applications of glyphosate over a ~~five~~ five-year period in an Ontario plantation have resulted in reduced microbial biomass, microbial carbon, soil organic carbon ratio, which indicates a reduced capacity of the ecosystem to maintain its nutrient reservoir (Ohtonen et al., 1992). In contrast, other field studies have found minimal or no effect on microbial processes or fungal community structures (Busse et al., 2001; Houston et al., 2002; Haney et al., 2002; Stratton and Steward, 1992; Chakravarty and Chatarpaul, 1990), while others have found a short-term increase in microbial activity caused by the breakdown of glyphosate and AMPA (Wardle and Parkinson 1990, Mijangos et al., 2009, Ratcliff et al., 2006, Haney et al., 2002). The extent of the variation in results suggests more research is needed in forest applications of glyphosate to better understand direct effects on microbial communities. Research should look at effects on individual species and the indirect impacts resulting from these changes in the ecosystem.

3.2.3 Glyphosate/AMPA fate in water

s.13

s.13

s.13

s.13

The main ways that glyphosate could end up in aquatic ecosystems are by drift onto non-target areas or by soil particle mobilization after a storm event in the hours following glyphosate application (Rolando 2017). These risks may be minimized in field operations using electronic guidance systems, low drift nozzles, and meteorological monitoring of wind speed, temperature and humidity (Thompson et al., 2012). In the field, studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken (Thompson et al., 2004, Feng and Thompson 1990; Gluns et al., 1989; Adams et al., 2007).

s.13

The primary mechanisms behind the rapid breakdown or reduction of glyphosate in the water column are adsorption into benthic or suspended sediments, microbial breakdown of glyphosate and its breakdown products, and downstream dilution. Glyphosate does persist longer in oligotrophic water bodies or those that are cold, deep and low in microbial activity. Residues have been detected in benthic sediments of these systems for up to 18 months after application (Feng et al., 1990; Newton et al., 1994; Newton et al., 1984)

3.3 Climate Change

The Intergovernmental Panel on Climate Change notes that "in the long-term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit" (Nabuurs et al., 2007). Vegetation management (including, but not limited to, glyphosate application) can affect carbon sequestration due to its impact on vegetation structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows the establishment of a woody crop delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools.

When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species. Mixedwood stands comprised of spruce and aspen are likely to have a higher yield than either pure spruce or pure aspen stands because of differences in shade tolerance, phenology, rooting patterns, and physical space occupied by different sized canopies (Gough et al., 2019, McCulloch and Kabzems 2009). Retaining between 1,000 and 10,000 stems/ha of aspen is expected to increase total stand production by approximately 20% relative to a pure spruce stand, but this will be at the expense of spruce volume (Kabzems et al., 2007). Harper and Roach (2014) similarly report that in a modeled mixedwood, the total stand volume is higher in a spruce-aspen mixedwood compared to pure spruce or pure aspen stands.

This effect varies with species, however. Growth and yield models in the SBS show that total stand volumes in lodegepole pine-aspen stands are not different from pure aspen or pure pine stands (Harper, 2015). In all cases, the increase of deciduous volume is at the expense of conifer volume (Kabzems et al., 2007; Harper and Roach, 2014; Harper, 2015).

Forest soils are the largest carbon pool in boreal and temperate ecosystems, often storing greater amounts of carbon than living biomass and coarse woody debris (Heath et al., 2003). Laganiere et al., (2017) found that aspen trees stored less carbon in the forest floor and similar amounts in the mineral soil relative to conifers. However, their study also showed that soil organic carbon stock under aspen is more stable, rendering it more protected against environmental changes and soil disturbances.

A source of uncertainty in determining the difference in carbon sequestration between mixedwoods and pure conifer stands stems from the shorter lifespan of deciduous trees compared to conifers, which ultimately affects the amount of time that a stand can act as a carbon sink (Harper and Roach, 2014).

3.4 Wildfire

Vegetation management (including, but not limited to, glyphosate application) has the potential of altering the amount of deciduous trees left on a site after regeneration. Deciduous stands often act as natural fire breaks. In summer months, deciduous stands moderate microclimates, inhibit wind movement, help maintain lower air temperature and higher humidity and maintain soil and surface fuel moisture longer into the fire season (Chesterman, 1997). s.13

s.13

The physical properties of aspen, in particular, resist intense fire behaviour (Alberta 2012), making it a popular choice for fuel treatments in the wildland urban interface throughout North America (Gray 2018, Shepperd et al., 2006). Usually, fire does not get carried into the crowns of deciduous stands due to the absence of ladder fuels. Consequently, fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires (Alexander and Lanoville, 2004). The FBP system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous[13] or leaf-on mixedwood stands. Amongst deciduous trees, poplars show the most fire resistance s.13

s.13

s.13

Table 5. Fire resistance of broadleaved species (BCMFLNRORD 2019).

Fire resistance/resilience	Broadleaved species
High	Balsam poplar, black cottonwood
High-Moderate	Gary oak, bigleaf maple
Moderate	Trembling aspen, red alder, paper birch
Low	Arbutus

3.5 First Nations

Some First Nations across BC have expressed concern over the use of glyphosate in forests. Some of these concerns relate to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated. Chief Ron Ignace (Skeetchestn Indian Band) has indicated that he considers the spraying of herbicide "an act of cultural genocide, because you are killing our foods and medicines."[14] The McLeod Lake Indian Band passed a Band Council resolution in July 2019 that reaffirms the Band's zero tolerance for herbicide, pesticide, insecticide and chemical fertilizer use within the traditional

[13] During spring months before leaf-out in deciduous stands, the grass has the potential to dry out rapidly in the absence of canopy cover, creating a higher surface fire potential until green-up and leaf-on occurs.

[14] https://acuriouslookatpoliticsinbc.blogspot.com/2019/09/adam-olsen-skeetchestn-indian-band.html?fbclid=IwAR3kXSjKGMzGu6V5qs4Gxvu9l06PdbVbL5TtjdfWvallemumCz0TiAsRnaQ

territory. The resolution indicates that glyphosate is deemed carcinogenic and has a direct impact on wildlife, ecosystems and water sources. Where there is doubt concerning the science about herbicides, there can be an inclination toward the precautionary principle.

Two-way education, communication, collaboration and joint problem solving between stakeholders is key to reaching agreements about land use. Traditional plant users should, for example, take into consideration that the presence of glyphosate does not indicate toxicity (Wood, 2019) or that plant diversity, richness and abundance is not generally not affected in the years following application. Similarly, forest managers need to acknowledge and communicate uncertainty regarding minor effects of glyphosate use. There is mounting evidence for example that Glyphosate/AMPA may persist in low levels in some perennial plants (Wood, 2019), and that it may also disrupt the creation of some plant secondary compounds, some of which may be the compounds responsible for medicinal effects in traditional medicines (Gomes et al., 2014).

s.13

s.13

- Designating no spray areas
- Prioritizing manual treatments
- Prioritizing backpack instead of aerial application
- Prioritizing spot spray around individual stems
- Increasing buffers
- Leaving untreated patches
- Providing alternative gathering sites
- Providing additional notification and signage
- Adjusting treatment schedules to avoid disrupting First Nation activities

3.6 Public Use

Forest managers are faced with mounting public pressure over the safety of glyphosate use (Thomson and Pitt, 2011). Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping or hiking. The Canada Pest Management Regulatory Agency's review on glyphosate (PMRA 2017) has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health. This applies to people that may come in contact to glyphosate from food or water, by handling the product or by entering treated sites.

There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues (including game species such as moose, deer and hare) (Lautenschlager, 1992; Legris and Couture, 1991; Newton et al., 1984). Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue (Wood, 2019). Where detected, glyphosate residue levels averaged 0.79 ppm (highest level detected was 4 ppm). From a food consumption perspective, 0.1 ppm is the maximum residue level (MRL) allowed for non-designated food in Canada, although this value ranges from 0.08 to 40 for specific foods.

Formatted: Not Highlight

s.13

s.13

4 IMPACTS ON TIMBER SUPPLY

Vegetation control, including but not limited to glyphosate application, is in some cases necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests. Vegetation management is one key tool to meet these objectives.

Glyphosate is used in this context because of its cost-effectiveness compared to manual vegetation control methods. Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked (NSR) area particularly problematic areas with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

In Canada, decisions to not use chemical herbicides have been taken in Quebec and Nova Scotia. In Quebec, a provincial ban of glyphosate use on Crown land took effect in 2001 after severe public pressure and a series of public consultations. Forest regeneration would focus on early planting of tall stock and intensive manual brushing. Since then, plantation establishment and tending costs in Quebec have frequently exceeded $5,000/ha due to planting large stock and as many as three manual brushing treatments (Labbé et al., 2014). Dampier et al. (2006) reported that cost per cubic metre of wood tripled when conifer release was performed by motor-manual methods rather than aerial application of herbicide.

s.13

An audit of plantations in Nova Scotia after a decision was made not to use herbicides yielded similar findings. Following a survey of untreated plantations, results showed 87% of conifer plantations were considered failures (with less than 60% stocking), and only 3% met free growing standards 6-8 years post-harvest (Nicholson, 2007).

In BC, meeting free growing stocking standards ensures that sustainable timber supply is achieved. In cases where aggressive competing vegetation cannot be overcome to the extent that is practicable in order to meet free growing requirements, licensees may request relief from reforestation obligations under FPPR sec 97.1. Increasing the challenge to meet reforestation obligations on a broad scale may increase the risk for reduced plantation performance with significant timber supply impacts, such as in the case of Quebec.

4.1 s.13

s.13

There are ongoing efforts to further develop standards that facilitate deciduous management in the context of overall forest management objectives. One example is the inclusion of fire stocking standards in the Wildland Urban Interface, including the establishment and management of deciduous species to reduce fire behaviour in areas near communities and infrastructure.[17] In another example, a Hardwood Management Strategy was developed in 2008 to facilitate management of red alder, bigleaf maple and birch in the Coast Region.[18] Wildlife stocking standards are also being developed and regional guidance is available.

15 http://www.fsjpilotproject.com/documents/SFMPappend2016/Appendix_6_Reforestation_Strategy_Stocking_Standards_and_Crop_Tree_Requirements.pdf

16 https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/stocking-standards

17 https://www.for.gov.bc.ca/hfp/silviculture/Fire%20Management%20Stocking%20Standards%20Guidance%20%20Document%20March%202016.pdf

18 https://www.for.gov.bc.ca/rco/stewardship/CRIT/docs/Hardwood%20Management%20in%20the%20Coast%20Forest%20Region%20(final%20July11V2).pdf

s.13

5 RECOMMENDATIONS

s.13

19 https://www.bcfpb.ca/wp-content/uploads/2019/07/SR58-Tactical-Forest-Planning.pdf

20 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-strategies/2018_final_merritt_iss_tactical_plan_v11.pdf

s.13

6 CONCLUSIONS

Glyphosate is one of many vegetation management tools available to forest managers. It is used to help maintain plantation survival and to meet free growing obligations that ensure stand productivity and sustainable timber supply. Forest managers are faced with mounting public pressure over the perceived environmental impacts of forestry applications of glyphosate. In particular, concerns over the removal of broadleaf tree species from the landscape and the consequent impacts on risk of wildfire, wildlife habitat, climate change, etc. A review of current inventory data however shows that stands that have been treated with glyphosate retain 15-21% deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.

Field studies have also shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals s.13
songbirds and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.

Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.

s.13

30

6 REFERENCES

Adams, G.W., Smith, T., and Miller, J.D. 2007. The Absence of Glyphosate Residues in Wet Soil and the Adjacent Watercourse after a Forestry Application in New Brunswick, Northern Journal of Applied Forestry, Volume 24, Issue 3.

Alexander, M.E., and Laneville, R.A. 2004. The International Crown Fire Modelling Experiment fuel treatment trials [abstract]. Page 222 in R.T. Engstrom, K.E.M. Galley, and W.J. de Groot (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

Baker, L. F., Mudge, J. F., Houlahan, J. E., Thompson, D. G. and Kidd, K. A. 2014. The direct and indirect effects of a glyphosate-based herbicide and nutrients on Chironomidae (Diptera) emerging from small wetlands. Environmental Toxicology and Chemistry 33:2076-2085.

Baker, L. F., Mudge, J.F, Thompson, D.G, Houlahan, J.E and Kidd, K.E. 2016. The combined influence of two agricultural contaminants on natural communities of phytoplankton and zooplankton. Ecotoxicology 25:1021-1032.

BC Ministry of Forests, Lands and Natural Resource Operations. 2008. Tree species composition and diversity in British Columbia. FREP Report #14.

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development. 2018, Silviculture Surveys Procedures Manual Regen Delay, Stocking and Free Growing Surveys plus Alternative Survey Methodologies. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

Bell, F. W. and Newmaster, S.G. 2002. The effects of silvicultural disturbances on the diversity of seed-producing plants in the boreal mixedwood forest. Can J. For Res. Vol 32 (7), p 1180-1191. https://digitalcommons.usu.edu/aspen_bib/389

Biring, B.S. and Hays-Byl, W.J. 2000. Ten-year Conifer and Vegetation Responses to Glyphosate Treatment in the SBSdw3. BC Ministry of Forests Extension Note 46.

Biring, B.S., Hays-Byl, W.J. and Hoyles, S.E., 1999. *Twelve-year conifer and vegetation responses to discing and glyphosate treatments on a BWBSmw backlog site*. British Columbia, Ministry of Forests Research Program.

Biring, B.S.; Comeau, P.G.; Fielder, P. 2003. Long-term effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in Southern British Columbia. Annals of Forest Science 60(7):681-690.14.

Boateng J.O., Heineman, J.L., McClarnon, J. and Bedford, L. 2006.Twenty year responses of white spruce to mechanical site prepara-tion and early chemical release in the boreal region of northeastern British Columbia. Can. J. For. Res. 36: 2386–2399.

Bureau du forestier en chef. 2015. Succes des plantations. Avis du Forestier en chef. FEC-AVIS-04-2015, Roberval, Quebec, 22 p. +annexes. http://forestierenchef.gouv.qc.ca/wpcontent/uploads/2015/12/fec-avis-04-201S.pdf

Busse, M.D., Ratcliff, A.W., Stestak, C.J., Powers, R.F. 2001. Glyphosate toxicity and the effects of long-term vegetation control on soil microbial communities. Soil Biology & Biochemistry, Vol. 33: 1777-1789.

Cakmak, I., Yazici, A., Tutus, Y. and Ozturk, L., 2009. Glyphosate reduced seed and leaf concentrations of calcium, manganese, magnesium, and iron in non-glyphosate resistant soybean. European Journal of Agronomy, 31(3), pp.114-119.

CCME (Canadian Council of Ministers of the Environment). 2012. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Glyphosate. In: Canadian environmental quality guidelines, Canadian Council of Ministers of the Environment, Winnipeg.

Chakravarty, P. and Chatarpaul, L., 1990. Non-target effect of herbicides: II. The influence of glyphosate on ectomycorrhizal symbiosis of red pine (Pinus resinosa) under greenhouse and field conditions. *Pesticide science*, *28*(3), pp.243-247.

Chesterman, D.A., 1997. Microclimate of aspen forests. University of Alberta M.Sc. thesis.

Cole, E., Youngblood, A. and Newton, M. 2003.Effects of competing vegetation on juvenile white spruce (Picea glauca(Moench)Voss) growth in Alaska. Ann. For. Sci. 60: 1–11

Comeau, P.G., Harper, G., Blache, M.E., Boateng, J.O. and Gilkeson, L., 1996. Integrated forest vegetation management: Options and applications.

Comeau, P.G., Biring, B.S. and Harper, G.J., 1999. Conifer response to brushing treatments: a summary of British Columbia data. Extension Note, British Columbia Ministry of Forests, (41), p.12.

Comeau, P.G., Biring, B.S., and Harper, G.J. 2000. Effectiveness of Repeated Manual Cutting and Glyphosate for Release of Engelmann Spruce from Mixed-Shrub Herb Vegetation. Western Journal of Applied Forestry 15(3):154-162. http://dx.doi.org/10.1093/wjaf/15.3.154

Comeau, P. and Fraser, E., 2018. Plant Community Diversity and Tree Growth Following Single and Repeated Glyphosate Herbicide Applications to a White Spruce Plantation. Forests, 9(3), p.107.

Comeau, P.G. and Harper, G.J., 2009. Effects of vegetation control treatments for release of Engelmann spruce from a mixed-shrub community in southern British Columbia Year 15 results. The Forestry Chronicle, 85(4), pp.583-592.

Connor, J.F. and McMillan, L.M., 1990. *Winter utilization by moose of glyphosate-treated cutovers*. Ontario Ministry of Natural Resources, Northwestern Ontario Forest Technology Development Unit.

Custer, T.W., Cox, E., & Gray, B. 2004. Trace elements in moose (Alces alces) found dead in Northwestern Minnesota, USA. Science of the Total Environment, 330(1): 81-87.

Dampier, E.E., Bell, F.W., St-Amour, M., Pitt, D.G., Luckai, N.J. 2006. Cutting versus herbicides: Tenth-year volume and release cost-effectiveness of sub-boreal conifer plantations. Forestry Chronicle 82(4):521-528. https://pubs.cif-ifc.o rg/doi/10.5558/tfc82521-4

Diaz, G., Carrillo, C., and Honrubia, M. 2003. Differential responses of ectomycorrhizal fungi to pesticides in pure culture. Cryptogam.: Mycol. 24: 199–211.

Druille, M., Cabello, M.N., Omacini, M. and Golluscio, R.A., 2013. Glyphosate reduces spore viability and root colonization of arbuscular mycorrhizal fungi. *Applied Soil Ecology*, *64*, pp.99-103.

Duke, S.O., Lydon, J., Koskinen, W.C., Moorman, T.B., Chaney, R.L. and Hammerschmidt, R., 2012. Glyphosate effects on plant mineral nutrition, crop rhizosphere microbiota, and plant disease in glyphosate-resistant crops. Journal of agricultural and food chemistry, 60(42), pp.10375-10397.

Duke, S.O., Rimando, A.M., Reddy, K.N., Cizdziel, J.V., Bellaloui, N., Shaw, D.R., Williams, M.M. and Maul, J.E., 2018. Lack of transgene and glyphosate effects on yield, and mineral and amino acid content of glyphosate-resistant soybean. Pest management science, 74(5), pp.1166-1173.

Dunbar, J., McCulloch, L. and Kabzems, R., 2011. Bluejoint Stand Establishment Decision Aid. Journal of Ecosystems and Management, 11(3).

Durkin, PR. Glyphosate - Human health and ecological risk assessment report. Syracuse Environmental Research Associates Inc, Fayetteville NY 2003.

Edge, C. B., Gahl, M.K., Pauli, B.D, Thompson, D.G. and Houlahan, J.E. 2011. Exposure of juvenile green frogs (Lithobates clamitans) in littoral enclosures to a glyphosate-based herbicide. Ecotoxicology and environmental safety 74:1363-1369.

Edge, C. B., M. K. Gahl, D. G. Thompson, and J. E. Houlahan. 2013. Laboratory and field exposure oftwo species of juvenile amphibians to a glyphosate-based herbicide and Batrachochytrium dendrobatidis. Science of the Total Environment 444:145-152.

Edge, C. B., D. G. Thompson, C. Hao, and J. E. Houlahan. 2012. A silviculture application of the glyphosate-based herbicide VisionMAX to wetlands has limited direct effects on amphibian larvae. Environmental Toxicology and Chemistry 31:2375-2383.

Edge, C., M. Gahl, D. Thompson, C. Hao, and J. Houlahan. 2014a. Variation in amphibian response to two formulations of glyphosate-based herbicides. Environmental Toxicology and Chemistry 33:2628-2632.

Edge, C., D. Thompson, C. Hao, and J. Houlahan. 2014b. The response of amphibian larvae to exposure to a glyphosate-based herbicide (Roundup WeatherMax) and nutrient enrichment in an ecosystem experiment. Ecotoxicology and Environmental Safety 109:124-132.

Edginton, A.N., Sheridan, P.M., Stephenson, G.R., Thompson, D.G. and Boermans, H.J., 2004. Comparative effects of pH and Vision® herbicide on two life stages of four anuran amphibian species. *Environmental Toxicology and Chemistry: An International Journal*, *23*(4), pp.815-822.

Ehrentraut, G., and Brantner, K. 1990. Vegetation management by manual and mechanical means in Alberta boreal forests. For. Chron. 66: 366–368.

Eker, S., Ozturk, L., Yazici, A., Erenoglu, B., Romheld, V. and Cakmak, I., 2006. Foliar-applied glyphosate substantially reduced uptake and transport of iron and manganese in sunflower (Helianthus annuus L.) plants. Journal of agricultural and food chemistry, 54(26), pp.10019-10025.

Eremko, R.D. 1986. The effects of the aerial application of Roundup on water quality in the Nicoamen River watershed. Unpubl.report for B.C. Min. For. & Lands, Lillooet District.

Eschholz, W.E., Servello, F.A., Griffith, B., Raymond, K.S., and Krohn, W.B. 1996. Winter use of glyphosate-treated clearcuts by moose in Maine. J. Wildl. Manage.60: 764–769

Estok, D., Freedman, B., and Boyle, D. 1989. Effects of the herbicides 2,4-D, glyphosate, hexazinone, and triclopyr on the growth of three species of ectomycorrhizal fungi. Bull. Environ. Contam. Toxicol. 42(6): 835–839. doi:10.1007/BF01701623. PMID: 2743015.

Feng, J.C. and D.G. Thompson. 1990. Fate of glyphosate in a Canadian forest watershed. 2. Persistence in foliage and soils. J. Agric. Food. Chem. 38:

Feng, J.C., Thompson, D.G., Reynolds, P.E. 1990. Fate of glyphosate in a Canadian forest watershed. 1. Aquatic residues and off-target deposit assessment. J. Agric. Food Chem. 1990, 38, 1110-1118.

Flynn, A., Franzmann, A.W., Arneson, P.D. and Oldemeyer, J.L., 1977. Indications of copper deficiency in a subpopulation of Alaskan moose. The Journal of Nutrition, 107(7), pp.1182-1189.

Folmar, L.C., Sanders, H.O. & Julin, A.M. Arch. Environ. Contam. Toxicol. (1979) 8: 269. https://doi.org/10.1007/BF01056243

Frank, A., Galgan, V. and Petersson, L.R., 1994. Secondary copper deficiency, chromium deficiency and trace element imbalance in the moose (Alces alces L.): effect of anthropogenic activity. Ambio (Sweden).

Freedman, B., Morash, R., and MacKinnon, D. 1993. Short-term changes in vegetation after the silvicultural spraying of glyphosate herbicide onto regenerating clearcuts in Nova Scotia, Canada. Can. J. For. Res.23:230D-2311.

Frey, B.R., Lieffers, V.J., Landhäusser, S.M., Comeau, P.G. and Greenway, K.J., 2003. An analysis of sucker regeneration of trembling aspen. Canadian Journal of Forest Research, 33(7), pp.1169-1179.

Giesy J.P., Dobson S., Solomon K.R. (2000) Ecotoxicological Risk Assessment for Roundup® Herbicide. In: Ware G.W. (eds) Reviews of Environmental Contamination and Toxicology. Reviews of Environmental Contamination and Toxicology, vol 167. Springer, New York, NY

Gluns, D.R. 1989. Herbicide residue in surface water following an application of Roundup® in the Revelstoke Forest District. B.C. Ministry of Forests and Lands. RR 88001-NE.

Goldsborough, L.G. and Beck, A.E., 1989. Rapid dissipation of glyphosate in small forest ponds. *Archives of Environmental Contamination and Toxicology*, *18*(4), pp.537-544.

Goldsborough, L.G. and D.J. Brown. 1993. Dissipation of glyphosate and aminomethylphosphonic acid in water and sediments of boreal forest ponds. Environ. Toxicol. Chem. 12:1139-1147

Gomes, M.P., Smedbol, E., Chalifour, A., Hénault-Ethier, L., Labrecque, M., Lepage, L., Lucotte, M. and Juneau, P., 2014. Alteration of plant physiology by glyphosate and its by-product aminomethylphosphonic acid: an overview. *Journal of experimental botany*, *65*(17), pp.4691-4703.

Gough, C.M, J.W. Atkins, R.T. Fahey and B.S. Hardaman. 2019. High rates of primary production in structurally complex forests, Ecology {2019). DOI: 10.1002/ecy.2864

Gray, R.W. 2018. Trembling aspen stands as firebreaks: what options are available for stimulating aspen stand expansion. City of Cranbrook, UBCM Fuel Management Pilot Program. https://wfca.ca/wpcontent/ uploads/2018/06/Trembling-Aspen-Stands-as-Firebreaks FINAL-REPORT.pdf

Guynn DC, Guynn ST, Wigley TB, Miller DA. 2004. Herbicides and forest biodiversity: what do we know and where do we go from here? WIldlife Society Bulletin. 2004; 32(4):1085-92.

Haney, R.L., Senseman, S.A. and Hons, F.M., 2002. Effect of Roundup Ultra on microbial activity and biomass from selected soils. *Journal of Environmental Quality*, *31*(3), pp.730-735.

Hagner, M., J. Mikola, I. Saloniemi, K. Saikkonen, M. Helander. 2019. Finnish ecological sustainability study: Glyphosate-based Roundup herbicide has 'minor, transient' impacts on soil and animal health. Scientific Reports (9)1: 8540. doi.org/10.1038/s41598-019-44988-5

Harper, G.J. 2015. Lodgepole pine and trembling aspen mixedwoods: Growth and yield within 22 to 39 year old pine plantations of northern interior British Columbia. For. Chron. 91(5): 502-518. https://www.researchgate.net/publication/291424207_Lodgepole_pine_and_trembling_aspen_mixedwoods_Growth_and_yield_within_22_to_39_year_old_pine_plantations_of_northern_interior_British_Columbia

Harper, G. 2017. Lodgepole pine and trembling aspen competition: Neighbourhood studies within 22 to 39 year old pine plantations of northern British Columbia. Forestry Chronicle, 2017, 93{3): 226-240, https:// doi .org/10.5558/tfc2017 -031

Harper, G.; Roach, J. 2014. The role of broadleaf trees: impacts of managing boreal and sub-boreal mixedwood forests in British Columbia. Extension Note- British Columbia Ministry of Forests and Range 2014 No.110 pp.8 pp.

Harper, G.J., Biring, B.C. and Heineman, J. 1997. Mackay River Herbicide Trial: Conifer Response 9 Years Post-treatment. BC Ministry of Forest Research Branch. Research Report 11.

Harper, G.J., Comeau, P.G. and Biring, B. S. 2005. A comparison of herbicide and mulch mat treatments for reducing grass, herb, and shrub competition in the BC Interior Douglas-fir zone—

Ten-year results. Western Journal of Applied Forestry, Volume 20, Issue 3, July 2005, Pages 167–176.

Hart, D. and Comeau, P.G. 1992. Manual brushing for forest vegetation management in British Columbia: A review of current knowledge and information needs. B.C. Ministry of Forests, Forest Science Research Branch. Land Management Report Number 77.

Hawkins, C.D.B.; Dhar, A.; Lange, J. 2013. Vegetation management with glyphosate has little impact on understory species diversity or tree growth in a sub boreal spruce plantation—A case study. Plant Biosyst. 2013, 147, 105–114.

Health Canada Pesticide Management Regulatory Agency. 2017. Re-evaluation decision glyphosate RVD2017-01. https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/registration-decision/2017/glyphosate-rvd-2017-01.html

Health Canada Pesticide Management Regulatory Agency. 2019. Statement from Health Canada on glyphosate. https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

Heath, L.S., Kimble, J.M., Birdsey, R.A. and Lal, R., 2003. The potential of US forest soils to sequester carbon. *In: Kimble, JM; Heath, Linda S.; Birdsey, Richard A.; Lal, R., eds. The potential of US forest soils to sequester carbon and mitigate the greenhouse effect. Boca Raton: CRC Press: 385-394.*

Heineman, J.L., S.W. Simard, D.L. Sachs and W.J. Mather. 2005. Chemical, grazing, and manual cutting treatments in mixed herb-shrub communities have no effect on interior spruce survival or growth in southern interior British Columbia. Forest Ecology and Management. Vol *205, 1-3,* p 359-374. https:// doi .org/10.1016/j. foreco.2004.10.038

Hjeljord, O. and Gr⊘ nvold, S., 1988. Glyphosate application in forest—ecological aspects: VI. Browsing by moose (Alces alces) in relation to chemical and mechanical brush control. *Scandinavian Journal of Forest Research*, *3*(1-4), pp.115-121.

Houlahan, J.E., C.S. Findlay, B.R. Schmidt, AH Meyer and S.L. Kuzmin. 2000. Quantitative evidence for global amphibian population declines. Nature 404. 752-755.

Houston, A.P.C., Visser, S. and Lautenschlager, R.A., 2002. Response of microbial processes and fungal community structure to vegetation management in mixedwood forest soils. Canadian journal of botany, 76(12), pp.2002-2010.

Howe, C.M., Berrill, C.M., Pauli, B.D., Helbing, C.C., Werry, K. and Veldhoen, N. 2004. Toxicity of glyphosate-based pesticides to four North American frog species. Environmental Toxicology and Chemistry: No. 23, pp. 1928–1938.

Kabzems, R., A.L. Nemec, and C. Farnden. 2007. Growing trembling aspen and white spruce intimate mixtures: Early results (13-17 years) and future projections. BC Journal of Ecosystems and management 8(1):1-14. uri: http://www.forrex.org/publications/jem/ISS39/vol8 no1 artl.pdf

Kabzems R. and G.J. Harper. 2015. Conifer and vegetation responses to pre-planting applications of glyphosate and hexazinone on a boreal backlog site, Sx trial 82502g-2. Prov. B.C., Victoria, B.C. Tech. Rep. 087. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr087.htm

Kissane, Z. and Shephard, J.M., 2017. The rise of glyphosate and new opportunities for biosentinel early-warning studies. Conservation biology, 31(6), pp.1293-1300.

Kuzyk, G., Marshall, S., Procter, C., Schindler, H., Schwantje, H., Gillingham, M., Hodder, D., White, S. and Mumma, M., 2018. Determining factors affecting moose population change in British Columbia.

Laatikainen, T., and Heinonen-Tanski, H. 2002. Mycorrhizal growth in pure cultures in the presence of pesticides. Microbiol. Res. 157(2): 127–137. doi:10.1078/0944-5013-00139. PMID: 12002401.

Lautenschlager, RA. 1992. Effects of conifer release with herbicides on moose: browse production, habitat use, and residues in meat. Alces 28:215-222

Lautenschlager, R.A., Dalton, W.J., Cherry, M.L., and Graham, J.L. 1999. Conifer release alternatives increase aspen forage quality in northwestern Ontario. J. Wildl. Manage.63: 1320–1326.

Labbé, F., Lainesse, M., Nadeau, F-R., Prégent, G., Savary, A. 2014. Analyse de rentabilité économique des plantations d'épinette noire et blanche et de pin gris. Bureau de mise en marché des bois, Québec (Québec). https://www.bmmb.gouv.qc.ca/analyses-economiques/.

Laganiere, J.; Boca, A.; Van Miegroet, H.; Pare, D. 2017. A tree species effect on soil that is consistent across the species' range: the case of aspen and soil carbon in North America . Forests 8: 113.

Lanctot, C., L. Navarro-Martin, C. Robertson, B. Park, P. Jackman, B. D. Pauli, and V. L. Trudeau. 2014. Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frog (Litho bates sylvaticus) tadpoles. II: Agriculturally relevant exposures to Roundup WeatherMax® and Vision® under laboratory conditions. Aquatic Toxicology 154:291-303.

Lanctot, C., C. Robertson, L. Navarro-Martin, C. Edge, S. D. Melvin, J. Houlahan, and V. L. Trudeau. 2013. Effects of the glyphosate-based herbicide Roundup WeatherMax® on metamorphosis of wood frogs (Litho bates sylvaticus) in natural wetlands. Aquatic toxicology 140-141:48-57.

Lautenschager, R.A. 1993. Response of wildlife to forest herbicide applications in northern coniferous ecosystems. Can. J. For. Res. 23: 2286-2299

Lautenschlager, R.A., and Sullivan, T.P. 2002. Effects of herbicide treatments on biotic components inregenerating northern forests. For. Chron.78: 1–37.

Legris, J.; Couture, G. Residus de Glyphosate dans le Gibier (Lievre, Orignal Qt cerf de Virginie) Suite a des Pulverisations en Milieu Forestier en 1988; Quebec Ministere des Forest, Direction de I' evaluation Environnementale: Charlesbourg, QC, Canada, 1991.

Lindgren, P.M.F., and T.P. Sullivan. 2001.1nfluence of alternative vegetation management treatments on conifer plantation attributes: abundance, species diversity, and structural diversity. For. Ecol. Manag. 142(1-3): 163-182

Macadam, A. and Kabzems, R. 2006. Vegetation Management Improves Early Growth of White Spruce More Than Mechanical Site Preparation Treatments, Northern Journal of Applied Forestry, Volume 23, Issue 1, March 2006, Pages 35–46, https://doi.org/10.1093/njaf/23.1.35

McCulloch, L. and R. Kabzems. 2009. British Columbia's northeastern forests: Aspen Complex Stand Establishment Decision Aid. BC Journal of Ecosystems and Management 10(2):51-58. www.forrex.org/publications/jem/ISS51/vol10 no2 art5.pdf

Meidinger and Pojar, 1991. Ecosystems of British Columbia. Special report Series 6, BC Ministry of Forests.

Mertens, M., Höss, S., Neumann, G., Afzal, J. and Reichenbecher, W., 2018. Glyphosate, a chelating agent—relevant for ecological risk assessment. Environmental Science and Pollution Research, 25(6), pp.5298-5317.

Mesnage, R., Defarge, N., De Vendômois, J.S. and Seralini, G.E., 2015. Potential toxic effects of glyphosate and its commercial formulations below regulatory limits. Food and Chemical Toxicology, 84, pp.133-153.

Mijangos, I., Becerril, J.M., Albizu, I., Epelde, L. and Garbisu, C., 2009. Effects of glyphosate on rhizosphere soil microbial communities under two different plant compositions by cultivation-dependent and-independent methodologies. *Soil Biology and Biochemistry*, *41*(3), pp.505-513.

Miller, D.T. 1985. Conifer release in the inland northwest - Effects p. 17-24 in weed control for forest productivity in the interior west. Symp Proce Spokane. WA February 5-7, 1985. Washington State University

Morgan, M.J., and J.W. Kiceniuk. 1992. Response of Rainbow trout to a two month exposure to Vision(!), a glyphosate herbicide. Bull. Environ. Contam. Toxicol. 48:772-780

Munson, A.D., Margolis, H.A. and Brand, D.G., 1993. Intensive silvicultural treatment: impacts on soil fertility and planted conifer response. *Soil Science Society of America Journal*, *57*(1), pp.246-255.

Nabuurs, J., Masera, 0., Andrasko, K., Benitez-Ponce, P., Boer, R., Dutschke, M., Elsiddig, E., FordRobertson, J., Frumhoff, P., Karjalainen, T., Krankina, 0., Kurz, W., Matsumoto, M., Oyhantcabal, W., Ravindranath, N., Sanz, M. Sanchez, T. and Zhang, X. 2007: Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group Ill to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. *Dave,* L.A. Meyer {eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NV, USA.

Navarro-Martin, L., C. Lanctot, P. Jackman, B. J. Park, K. Doe, B. D. Pauli, and V. L. Trudeau. 2014. Effects of glyphosate-based herbicides on survival, development, growth and sex ratios of wood frogs (*Litho bates sylvaticus*) tadpoles. 1: Chronic laboratory exposures to Vision Max®. Aquatic Toxicology 154:278-290.

Navratil, S., K. Branter and J. Zasada. 1991.Regeneration in the mixedwoods. InA. Shortreid (ed.). Proc. of the Symposium onNorthern Mixedwoods '89. Sept. 12-14, 1989, Fort St. John, BC.FRDA Report 164, Forestry Canada, Pacific Forestry Centre. pp.32–48.

Newsome, T.A. and J.L. Heineman. 2016. Adjusting free-growing guidance regarding aspen retention in the Cariboo-Chilcotin: research to operational implementation. Prov. B.C., Victoria, B.C. Tech Rep 102. https://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/TR102.htm

Newton, M., Cole, E.C., Lautenschlager, R.A., White, D.E., and McCormack, M.L., Jr. 1989. Browse availability after conifer release in Maine's spruce-fir forests. J. Wildl. Manage.53: 643–649.

Newton, M,; Howard, K.M.; Kelpsas, B.R.; Danhaus, R.; Lottman, C.M.; Dubelman, S. 1984. Fate of glyphosate in an Oregon forest. Journal of Agricultural and Food Chemistry 32:1144-1151

Newton M, Howard KM, Kelpsas BR, Danhaus R, Lottman CM, Dubelman S. 1984. Fate of glyphosate in an Oregon forest. Journal of Agricultural and Food Chemistry. 1984; 32:1144-51

Newton M, Horner LM, Cowell JE, White DE, Cole EC. Dissipation of glyphosate and aminomethylphosphonic acid in North American forests. Journal of Agricultural and Food Chemistry. 1994; 42(8):1795-802

Nicholson, J. 2007. Survey of plantations established between 1998-2000 (6-8 years of age) on eastern Crown land without herbicides.: Nova Scotia Department of Natural Resources, Forest Management Planning, Forest Research Report 83, 27 p

O'Hara, T.M., Carroll, G., Barboza, P., Mueller, K., Blake, J., Woshner, V. and Willetto, C., 2001. Mineral and heavy metal status as related to a mortality event and poor recruitment in a moose population in Alaska. Journal of Wildlife Diseases, 37(3), pp.509-522.

Ohtonen, R., Munson, A. and Brand, D., 1992. Soil microbial community response to silvicultural intervention in coniferous plantation ecosystems. *Ecological Applications*, *2*(4), pp.363-375

Perala, D.A., 1985. Using glyphosate herbicide in converting aspen to conifers. Research Paper, North Central Forest Experiment Station, USDA Forest Service, (NC-259).

Pesticide Management Regulatory Agency, 2015. Glyphosate revaluation decision RVD2015-1. Health Canada.

Pesticide Management Regulatory Agency, 2017. Glyphosate revaluation decision RVD2017-1. Health Canada.

Pitt, D.G. and Bell, F.W., 2005. Juvenile response to conifer release alternatives on aspen-white spruce boreal mixedwood sites. Part I: Stand structure and composition. The Forestry Chronicle, 81(4), pp.538-547.

Pitt, D.G., R.G. Wagner and W.D. Towill. 2004a.Ten years of veg-etation succession following ground-applied release treatments in young black spruce plantations. North. J. Appl. For. 21(3): 123–134

Pitt, D.G., Mihajlovich, M. and Proudfoot, L.M., 2004b. Juvenile stand responses and potential outcomes of conifer release efforts on Alberta's spruce aspen mixedwood sites. The Forestry Chronicle, 80(5), pp.583-597.

Raymond, K.S., Servello, F.A., Griffith, B., and Eschholz, W.E. 1996. Winter foraging ecology of moose onglyphosate-treated clearcuts in Maine. J. Wildl. Manage.60: 753–763

Ratcliff, A.W., Busse, M.D. and Shestak, C.J., 2006. Changes in microbial community structure following herbicide (glyphosate) additions to forest soils. *Applied Soil Ecology*, *34*(2-3), pp.114-124.

Reddy, K.N., Rimando, A.M., Duke, S.O. 2004. Aminomethylphosphonic acid, a metabolite of glyphosate, causes injury in glyphosate-treated, glyphosate-resistant soybean. Journal of Agricultural and Food Chemistry 52, 5139–5143

Reynolds, P .E., Scrivener, J.C., Holtby, LB. and Kingsbury, P.D., 1993. Review and synthesis of Carnation Creek herbicide research. The Forestry Chronicle, 69(3), pp.32.3-330.

Rolando, C.A.; Baillie, B.R.; Thompson, D.G.; Little, K.M . 2017. The risks associated with glyphosate-based herbicide use in planted forests. Forests 8(6): 208-233. https://www.mdpi.com/1999-4907/8/6/208

Rzymski, P., Klimaszyk, P., Kubacki, T. and Poniedziałek, B. 2013. The effect of glyphosate-based herbicide on aquatic organisms – a case study. Limnological Review. 13(4):215-220

Sanogo, S., Yang , X.B., and Scherm, H. 2000. Effects of herbicides on Fusarium solanif. sp. glycines and development of sudden death syndrome in glyphosate-tolerant soybean. Phytopathology, 90(1): 57–66. doi:10.1094/PHYTO.2000.90.1.57.PMID:18944572.

Santillo, D.J., Leslie, D.M., Jr., and Brown, P.W. 1989a. Responses of small mammals and habitat to glyphosate application on clearcuts. J. Wild. Manage. 53: 164-172.

Shepperd, Wayne D.; Rogers, Paul C.; Burton, David; Bartos, Dale L. 2006. Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada. Gen. Tech. Rep. RMRS-GTR-178. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station 122 p.

Simard, S. 2001. Effects of Operational Brushing on Conifers and Plant Communities in the Southern Interior of British Columbia: Results from PROBE 1991-2000, PRotocol for Operational Brushing https://www.for.gov.bc.ca/hfd/pubs/docs/Lmh/Lmh48.pdf

Simard, S. and A. Vyse. 2006 Trade-offs between competition and facilitation: a case study of vegetation management in the interior cedar-hemlock forests of southern British Columbia. Canadian Journal of Forest Research, 2006, 36(10): 2486-2496, https://doi.org/10.1139/x06-150

Simard, S. and A. Vyse. 2006 Trade-offs between competition and facilitation: a case study of vegetation management in the interior cedar-hemlock forests of southern British Columbia. Canadian Journal of Forest Research, 2006, 36(10): 2486-2496, https://doi.org/10.1139/x06-150

Sullivan, T.P. and D.S. Sullivan. 2003. Vegetation management and ecosystem disturbance impact of glyphosate herbicide on plant and animal diversity in terrestrial ecosystems. Environ. Rev. 2013: 11:37-59.

Sullivan TP, Sullivan OS. Vegetation management and ecosystem disturbance: impact of glyphosate herbicide on plant and animal diversity in terrestrial systems. Environmental Review. 2003; 11:37-59.

Székács, A. & Darvas, B., 2012. Forty years with glyphosate. in Herbicides - Properties, Synthesis and Control of Weeds, M. N. A. E.-G. Hasaneen, Ed., InTech, Rijeka, Croatia, 2012.

Tanney, J. B., & Hutchison, L. J. 2010. The effects of glyphosate on the in vitro linear growth of selected microfungi from a boreal forest soil. Canadian journal of microbiology, 56(2), 138-144.

Taylor, S.W., R.G. Pike and M.E. Alexander. 1996. Field guide to the Canadian forest fire behaviour prediction (FPB) system. FRDA Handbook 012. https://www.for.gov.bc.ca/hfd/pubs/Docs/Frh/Frh012.pdf

Tarazona, Jose V.; Court-Marques, Daniele; Tiramani, Manuela; Reich, Hermine; Pfeil, Rudolf; lstace, Frederique;Crivellente, Federica (April3, 2017). "Giyphosate toxicity and carcinogenicity: a review of the scientific basis of the European Union assessment and its differences with IARC". Archives of Toxicology. 91 (8): 2723-2743.

Tesfamariam, T., Bott, S., Cakmak, I., Römheld, V. and Neumann, G., 2009. Glyphosate in the rhizosphere—Role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants. European journal of agronomy, 31(3), pp.126-132.

Thiffault, N. & Roy, V. 2011. Living without herbicides in Québec (Canada): historical context, current strategy, research and challenges in forest vegetation management. Eur J Forest Res (2011) 130: 117. https://rd.springer.com/article/10.1007/s10342-010-0373-

Thompson, D.G. and Pitt, D.G., 2011. Frequently asked questions (FAQs) on the use of herbicides in Canadian Forestry. *forest*, *13*, p.14.

Thompson DG, Pitt DG, Buscarini TM, Staznik B, Thomas DR. 2000. Comparative fate of glyphosate and triclopyr herbicides in the forest floor and mineral soil of an Acadian forest regeneration site. Canadian Journal of Forest Research. 30:1808-16.

Thompson DG, Pitt DG, Staznik B, Payne NJ, Jaipersaid D, Lautenschlager RA, et al., 1997. On-target deposit and verticle distribution of aerially released herbicides. For. Chron. 73(1):47-59.

Thompson, D.G, Wojtaszek, B.F., Staznik, B., Chartband, D.T., Stephenson, R. 2004. Chemical and biomonitoring to assess potential acute effects of VisonR herbicide on native amphibian larvae in forest wetlands. Environ Toxicol Chem 2004;23:843– 9.

Thompson, D., Leach, J., Noel, M., Odsen, Sand Mihajlovich, M. 2012. Aerial forest herbicide application: comparative assessment of risk mitigation strategies in Canada. For. Chron. 88(2) 176-184.

Wan, M.T., Watts, R.G. & Moul, D.J. 1989. Effects of different dilution water types on the acute toxicity to juvenile pacific salmonids and rainbow trout of glyphosate and its formulated products. Bull. Environ. Contam. Toxicol. (1989) 43: 378. https://doi.org/10.1007/BF01701872

Wardle, D.A. and Parkinson, D., 1990. Influence of the herbicide glyphosate on soil microbial community structure. Plant and Soil, 122(1), pp.29-37.

Whitehead, R.J and Harper, G.J. 1998. A comparison of four treatments for weeding Engelmann spruce plantations in the Interior Cedar Hemlock Zone of British Columbia: ten years after treatment. Canadian Forest Service Information report (Pacific Forestry Centre); BC-X-379

Wood, J.E. and F.W. von Althen. 1993. Establishment of whitespruce and black spruce in boreal Ontario: Effects of chemical site preparation and post-planting weed control. For. Chron. 69:554–560.

Wood, J.L. 2019. The presence of glyphosate in forest plants with different life strategies one year after application. Canadian Journal of Forest Research, 2019, 49(6): 586-594, https://doi.org/10.1139/cjfr-2018-0331

Zaller, J.G., Heigl, F., Ruess, L. and Grabmaier, A., 2014. Glyphosate herbicide affects below ground interactions between earthworms and symbiotic mycorrhizal fungi in a model ecosystem. Scientific reports, 4, p.5634.

APPENDIX 1. INTERNATIONAL ASSESSMENTS

Various international expert panels and regulators have reviewed glyphosate and its effect on human health. The consensus among national pesticide regulatory agencies and scientific organizations is that labeled uses of glyphosate have demonstrated no evidence of human carcinogenicity (Tarazona et al., 2017).

IARC

In March 2015, the World Health Organization's (WHO) International Agency for Research on Cancer (IARC), consisting of 17 experts from 11 countries, classified glyphosate as "probably carcinogenic in humans" based on epidemiological studies, animal studies, and in vitro studies[21]. This was based on "limited" evidence of cancer in humans (from real-world exposures that actually occurred) and "sufficient" evidence of cancer in experimental animals (from studies of "pure" glyphosate). "Limited" evidence means that a positive association has been observed between exposure to the agent and cancer but that other explanations for the observations (called chance, bias, or confounding) could not be ruled out.

IARC also concluded that there was "strong" evidence for genotoxicity, both for "pure" glyphosate and for glyphosate formulations[22].

EFSA

The European Food Safety Authority (EFSA) of the European Union (EU) concluded in Oct. 2015 that "the substance is unlikely to be genotoxic (i.e. damaging to DNA) or to pose a carcinogenic threat to humans"[23].

Glyphosate was not proposed to be classified as carcinogenic under the EU regulation for classification, labelling and packaging of chemical substances. In particular, all the Member State experts but one agreed that neither the epidemiological data (i.e. on humans) nor the evidence from animal studies demonstrated causality between exposure to glyphosate and the development of cancer in humans. A supplementary document clarified that while carcinogenic glyphosate-containing formulations may exist, studies "that look solely at the active substance glyphosate do not show this effect[24].

21 https://www.iarc.fr/featured-news/media-centre-iarc-news-glyphosate/

22 https://monographs.iarc.fr/wp-content/uploads/2018/06/mono112-10.pdf

23 http://www.efsa.europa.eu/en/efsajournal/pub/4302

24 http://www.efsa.europa.eu/sites/default/files/4302_glyphosate_complementary.pdf

Joint FAO/WHO

The WHO and FAO Joint committee on pesticide residues issued a report in 2016 stating the use of glyphosate formulations does not necessarily constitute a health risk and giving admissible daily maximum intake limits (one milligram/kg of body weight per day) for chronic toxicity[25].

EPA

In 2017, the American Environmental Protection Agency (EPA) classified glyphosate as "not likely to be carcinogenic to humans"[26]. The Agency's assessment found no other meaningful risks to human health when the product is used according to the pesticide label.

ECHA

In March 2017, the Committee for Risk Assessment of European Chemicals Agency (ECHA) concluded that the available scientific evidence did not meet the criteria to classify glyphosate as a carcinogen, as a mutagen or as toxic for reproduction. However, it was classified as causing serious eye damage and toxic to aquatic life with long lasting effects[27].

APVMA

In 2017 the Australian Pesticides and Veterinary Medicines Authority (APVMA) reviewed the IARC monograms and other international assessments and concluded that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans[28]. APVMA provides a good on-line overview of various studies and issues as well as an explanation of the IARC assessment[29].

California

Agreeing with the IARC classification, California listed glyphosate as a known carcinogen on July 7, 2017, under Proposition 65 law, which would require indicating this carcinogenicity hazard on the product label of glyphosate-based herbicide products. However, in response to a legal claim by an agricultural coalition including the National Association of Wheat Growers, Monsanto Corporation and farmer groups, the U.S. District Court issued a preliminary injunction against this evaluation on the basis that the classification by IARC claims glyphosate only probably carcinogenic, while apparently all other regulatory and governmental bodies found the opposite, including the US EPA[30].

Canada

In 2015 Health Canada's Pest Management Regulatory Agency (PMRA) released a Proposed Re-evaluation Decision document on glyphosate[31]. This consultation document described the registration process for the use of herbicides in Canada and summary of the science evaluated

25 https://www.who.int/foodsafety/areas_work/chemical-risks/JMPR_2016_Report_May.pdf

26 https://www.epa.gov/pesticides/epa-releases-draft-risk-assessments-glyphosate

27 https://echa.europa.eu/-/glyphosate-not-classified-as-a-carcinogen-by-echa

28 https://apvma.gov.au/sites/default/files/publication/26561-glyphosate-final-regulatory-position-report-final_0.pdf

29 https://apvma.gov.au/node/13891

30 https://www.frontiersin.org/articles/10.3389/fenvs.2018.00078/full

31 http://publications.gc.ca/collections/collection_2015/sc-hc/H113-27-2015-1-eng.pdf

and the reasons for the proposed re-valuation decision. Input comments were solicited. Registered pesticides are re-evaluated by PMRA on a cyclical basis to ensure they meet modern health and environment safety standards and continue to have value. In April, 2017, Health Canada reapproved glyphosate. The Re-evaluation Decision document[32] summarizes the agency's final decision on glyphosate, the reasons for it and PMRA's response to comments received. An evaluation of the available scientific information found that products containing glyphosate do not present risks of concern to human health or the environment when used according to the revised label directions. As a requirement for the continued registration of glyphosate uses, new risk reduction measures were required for the end-use products registered in Canada. These included a restricted-entry period of 12 hours for agricultural uses, directions to apply when potential for drift into areas of human activity is minimised, environmental hazard statements, spray buffer zones, precautionary statements and use restrictions to reduce runoff to aquatic areas.

Following Canada Health's re-evaluation decision of 2017, eight notices of objection were received. There were also public concerns about the validity of the science as indicated in the so called 'Monsanto Papers'. On January 11, 2019, Health Canada issued a statement indicating that after a thorough scientific review, objections to glyphosate use could not be scientifically supported when considering the entire body of relevant data[33].

32http://publications.gc.ca/collections/collection_2017/sc-hc/H113-28/H113-28-2017-1-eng.pdf

33 https://www.canada.ca/en/health-canada/news/2019/01/statement-from-health-canada-on-glyphosate.html

APPENDIX 2. STOCKING STANDARDS AND SURVEY CHANGES RELATED TO DECIDUOUS MANAGEMENT IN BC

2007: Recognizing the autecology of the competition species, specifically shrub and herb compared to broadleaf species (deciduous), and the effects of these specific competitors on managed coniferous stands;

2007: Using improved free growing decision-making tools, via the quadrant method to evaluate free growing and 'potentially' free growing trees at the plot level, considering:

• site series specific competition thresholds;

• competition thresholds specific to the silvics of managed crop species.

This is a more refined evaluation method in the Coast, North and South Areas, when compared to simply evaluating competition within a 1 m cylinder with standard crop to brush ratios, as used in the past.

2009: Employing regionally developed brush competition assessments, specific to many BEC variants in the three Cariboo Timber Supply Areas (TSAs) based on empirical data collected by silviculture researchers. This neighbourhood concept has led to a greater flexibility in crop trees being assessed as free growing when intermixed and overtopped by broadleaf competition. As well, certain BEC variants in the Cariboo consider broad leaf competition as 'non-deleterious', thus not affecting their status as free growing;

2011: Developing new Broadleaf Forest Health Free Growing Damage Criteria, used to assess the acceptability of broadleaves as free growing, given these deciduous species are specified as crop trees in an approved Forest Stewardship Plan;

2018: Expanding the 'non-deleterious' definition of broadleaf competition, in conifer managed stands, to all site series within the IDFdk4 and SBPSxc BEC variants within the three Cariboo TSAs.

APPENDIX 3. INTEGRATED PEST MANAGEMENT PRINCIPLES

Elements of Integrated Vegetation Management include:

1. Prevention

2. Pest Identification

3. Seedling and Vegetation Monitoring

4. Injury Thresholds and Treatment Decisions

5. Treatment Options and Selection Criteria

6. Post-Treatment Effectiveness Evaluation

Prevention

Prevention of vegetation competition issues can be done through:

- **Site preparation:** The intent of site preparation is to reduce the impacts of growth limiting factors that might inhibit seedling establishment or growth potential.
- **Planting:** Stock with high genetic worth can improve survival performance of planted seedlings. Similarly, large seedling stock that is tall with good diameter is better suited to compete for light and can withstand higher brush hazards.
- **Species selection:** Species selection is made based on the ecological suitability of a species to the specific site conditions on an area. Additional considerations include immediate and long-term forest health factors, future forest products, volume and value, climate change, and consistency with the Timber Supply Analysis.
- **Regeneration delay:** Seedlings that are quickly established are more likely to compete successfully with problematic vegetation. Especially on brush prone sites, seedlings should be planted as soon as possible following harvesting.
- **Microsite selection:** Seedlings that are planted in the best microsite possible and that remain undamaged during the planting process are more likely to compete successfully with problematic vegetation.
- **Fertilization:** Fertilization treatments can potentially improve seedling establishment and reduce the need for brushing.
- **Advanced regeneration**: Another stand establishment option is to utilize advanced growth in the understory at the time of harvest. This could involve partial cuts such as shelterwood silviculture systems where silvics and site conditions are appropriate.

Pest identification

In the context of vegetation management, the term "pest" refers to herbaceous, shrub and broadleaf complexes or communities that:

- Inhibit plantation establishment;
- Hinder optimal growth and development of crop trees;

- Prevent a stand from achieving free growing;
- Affect an established plantation's overall health; or,
- When combined with snow, causes damage to crop trees by snow press.

Identification of potential vegetation problems starts with sound ecosystem classification from which vegetation complexes can be predicted. Post-harvest assessments and seedling monitoring can also help in identifying potential or realized brush problems.

Seedling and vegetation monitoring

Surveys and walkthroughs are scheduled throughout the plantations' development in order to ensure that stocking and brush levels are acceptable and that free growing parameters will be achieved within the appropriate time frame. Monitoring includes post-harvest assessments, regeneration delay surveys, regeneration performance walkthroughs, and free growing surveys.

Injury Thresholds and Treatment Decisions

Decisions to control vegetation on a site may be based on a number of different protocols depending on regional and ecological parameters. Measures such as competition index (CI) and height to diameter ratio (HDR) may be used to determine whether competing vegetation is negatively impacting crop trees. Crop tree status and vigour may also be evaluated based on local knowledge or % of crop trees that are overtopped, threatened, or above the brush.

Competition Index (CI) is a simple index that measures the competition for sunlight with regards to crop trees. CI is calculated as the sum of the products of cover and height for all non-crop species within a 1.26 meter radius around a crop tree, divided by crop-seedling height. CI shows that growth declines with increases in competition index. There is a very rapid decline in growth as CI increases from 0 to 100. At CI=100, growth is approximately 60% of that of a seedling growing free from competition. At a CI=150, seedlings receive 30% of the full sunlight in midsummer and would achieve approximately 45% of potential growth rates (Comeau et al., 1993). Treatment may be recommended when CI>80.

Height to diameter ratio (HDR) of crop trees can indicate sturdiness. In low light conditions, conifers will put more resources toward height growth, making them susceptible to vegetation and snow press. Treatment may be recommended with HDR>40 or 50, depending on species, where >50% of stems exceed the HDR.

Vegetation Management Options and Selection Criteria

Aerial Application

Broadcast treatment with a helicopter equipped with low-pressure boom and high-volume nozzles. Variable application rates are possible. May control brush for 2-4 years.

Discretionary, non-continuous application across portions of the block can also be applied.

The most cost-effective treatment and the safest option for workers on the ground

Benefits	Limitations
• Effective control for a number of years	• Less selective than other methods

• Minimal contact of chemical to workers	• Stringent application constraints
• Low cost	• Intensive prep and follow up
• Can treat remote, steep, slashy ground more safely than alternatives	• High public profile
	• Residual leave trees are obstacles
• Can treat large areas in short time	• Visual quality affected for years
	• Technically demanding
	• Drift can occur outside treatment areas

Backpack Application

Backpack broadcast - continuous application across treatment unit with low-pressure backpack sprayer with adjustable nozzles. Variable application rates are possible. May control brush for 2-4 years. Discretionary non-continuous, or spot treatment can be applied.

Benefits	Limitations
• Effective control for a number of years	• Stringent application constraints
• Can treat blocks with standing residuals	• Intensive prep and follow up
• Selective. Can apply with precision	• Requires high level of supervision
• Only small buffers needed on Pesticide Free Zones	• Exposure of workers to herbicide
	• Safety concerns wearing heavy equipment on rough terrain
	• Access and water availability
	• Constrained by brush height
	• Inconsistent results from dew, rainfall and missed spots that are difficult to detect during monitoring.
	• Safety concerns evacuating from remote sites
	• Crew availability

Cut Stump

Selective application of herbicide onto a cut stump of target vegetation. Brush saw or power saw cuts stump and a worker applies herbicide using a backpack sprayer, squeeze bottle or nozzle mounted on the saw. May control brush for about 4 years.

Benefits	Limitations
• Effective control for a number of years,	• Stringent application constraints prevents resprouting (lowest limb)
• Longer treatment window	• Intensive prep and follow up
• Little herbicide exposure to workers	• Requires high level of supervision
• Only small buffers needed on Pesticide Free Zones	• Exposure of workers to herbicide
	• Safety hazards operating powersaws
• Low application rate	• Safety concerns wearing heavy equipment on rough terrain

Motor Manual

Workers cut target vegetation with powersaws or brush saws. May control herbaceous brush for less

than a year, deciduous brush for about 2 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatment
• Public acceptance	• Safety hazards operating powersaws
• Can be applied selectively	• Expensive treatment cost
• Can be used in PFZ buffers	• Relative short window for treatment
• Not effective on herbaceous	• Limited availability of workers
	• Slash loads can be fire hazards, limit trafficability

Hand Tools

Workers treat spots around crop trees with handheld cutters.

Girdling hardwoods to remove a continuous strip bark around circumference which kills trees 2-3 years later.

Snap/hinge- partially breaking smaller stems by hand.

May control brush for less than a year. Girdling can control brush for about 3 years.

Benefits	Limitations
• No herbicide use	• Resprouting, may require multiple treatment
• Public acceptance	• Expensive treatment cost
• Can be applied selectively	• Repetitive strain injuries are common
• Can be used in PFZ buffers	• Limited availability of workers
's.13	• Girdling not effective on herbaceous

Sheep Grazing

Shepherds guide a flock of sheep (1,000-1,500} through treatment areas where they eat target

vegetation. May control brush for a year.

Benefits	Limitations
• No herbicide use	• Expensive treatment cost
• Not constrained by weather	• Some crop tree damage
• Safe for workers	• Herbaceous, limited height
	• Need good access, gentle terrain, low slash, blocks in proximity
	• Risk of disease to wildlife

• Risk from predators

Mechanical Site Preparation

Mechanically creating favourable planting spots that mitigate limiting site factors such as cold, poorly

aerated soils, competing vegetation and frost risk. Where brush hazards are high, mounding is preferred so seedlings are elevated, receive more light and vegetation falls away from crop trees rather than pressing over them. Mounding is done with excavators or implements attached to prime movers such as skidders. May control brush for 3-5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Public acceptance	• Access and soil disturbance
• Increased soil temperature	• Site constraints- trafficability
• Facilitates planting	• Availability of contractors in the north

Prescribed Burning

Prescribed burning is another form of site preparation using ground crews or a helicopter to apply a

controlled burn. May control brush for 3-5 years.

Benefits	Limitations
• No herbicide use	• Expensive
• Good seedbed, plantable spots	• Liability and risk of escape
	• Smoke and health effects
	• Risks to workers

Treatment Selection

Treatment methods for a specific site will be selected based on a number of factors including safety concerns, timing, treatment efficacy, cost, biophysical constraints, legal constraints, political constraints and concerns from other users and stakeholders. Some of these factors include:

- **Target species height**: Backpack treatments cannot be sprayed overhead. Sheep are also constrained by their ability to reach foliage and are restricted to sites with vegetation of <1m in height.
- **Target species diameter**: Girdling becomes impractical at diameters of less than 3 cm or greater than 10 cm.
- **Target species distribution**: Broadcast foliar treatments are not effective if target species are in clumps. Discretionary treatments are less appropriate if the target brush is evenly distributed.

- **Physical impediments to treatment**: Aerial treatments can be limited by residual trees, or small, irregular shaped treatment units. Ground-based treatments can be affected by steep slopes, uneven terrain, slash loading, difficult access and remote access.
- **Buffers**: Blocks with many features that require No Treatment Zones and Pesticide Free Zones (PFZs), such as water bodies, wetlands, roads, etc, may have little treatable area for herbicide treatments once all the buffers are established.
- **Timing**: Chemical treatment windows are small and require conifers hardening off to avoid chemical damage while target species are still succulent. Motor manual treatment windows may overlap with fire season and are dependent on fire risk safety measures.
- **Special wildlife features**: Heavy browsing might reduce the need for brushing if there is little alternative browse available. Treatments that create heavy slash loads that restrict game movement may be avoided. Sheep grazing may be a poor choice in high grizzly bear use areas.
- **Vulnerable plant species**: Vulnerable plant species are defined as those plants whose numbers are either limited or are important for browse or forage. Vulnerable plant species must be protected from broadcast treatments where identified.
- **First Nations rights infringement**: When specific information indicates that there is a higher likelihood of treatments infringing on First Nations rights on a unit, certain treatments may be considered unsuitable, or modified. For example, if consultation with a First Nation produced indicated that a specific site is used for berry-picking, a broadcast chemical treatment would be considered inappropriate.
- **Potential for conflict**: Some proposed treatments may result in an unacceptable risk of conflict with the public, First Nations or other stakeholders.
- **Potential for crop tree damage**: Heavy slash loading from motor-manual treatments could mechanically damage crop trees. It can be hard to spot crop trees in dense vegetation which can result crop tree damage. Brushing can increase the risk of root rot spreading. Slash loading or dead stems can also create fire risks.
- **Availability of crews**: It is increasingly difficult to attract workers to the silviculture industry and brushing is onerous physical work. Safety is also a factor as higher numbers of injury claims are associated with higher claim payments for brushing and weeding. Fewer people are engaging in this sector (Dilkina 2019). The area manually brushed, 11,600 ha in 2018, would have to double to treat the sprayed area, so manpower availability would be limiting.

Post-treatment effectiveness evaluation

s.13

s.13

Environmental Protection Strategies and Procedures

s.13

(including herbicide transportation, storing, mixing, loading, disposal) and the environmental safeguards in place regarding herbicide field application, including:

- Strategies to protect community watersheds and other domestic water sources

- Strategies to protect fish and wildlife, riparian areas, and wildlife habitat
- Pesticide free zones (PFZ)
- Species at Risk
- Strategies to prevent herbicide treatment of food intended for human consumption
- Pre-treatment inspection procedures for identifying treatment area boundaries
- Weather monitoring and strategies
- Procedures for maintaining and calibrating herbicide application equipment

GLOSSARY

s.13

FLNRORD	BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FRPA	Forest Range and Practice Act
FSP	Forest Stewardship Plan
FPPR	Forest Planning and Practices Regulation

s.13

PMP	Pest Management Plan
PMRA	Health Canada Pest Management Regulatory Agency
RESULTS	Reporting Silviculture Updates and Land Status Tracking System

s.13



info@fpinnovations.ca
www.fpinnovations.ca

OUR OFFICES

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
(514) 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
(604) 224-3221

Québec
1055 rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
(418) 659-2647

Begon, Stacey FLNR:EX

Subject:	Next steps re: glyphosate report
Location:	Online Meeting
Start:	Fri 2019-11-29 1:00 PM
End:	Fri 2019-11-29 2:00 PM
Show Time As:	Tentative
Recurrence:	(none)
Organizer:	Hedges, Shawn FLNR:EX
Required Attendees:	Bedford, Lorne FLNR:EX; Hughes, Neil FLNR:EX; Psyllakis, Jennifer FLNR:EX; MacDougall, Julie FLNR:EX; Berg, Shane FLNR:EX; Uppenborn, Jeremy GCPE:EX; Gordon, Steve M FLNR:EX; Mullan, Jonathan M ENV:EX

Colleagues, as per recent email communication, I would like to discuss what to include in the minister/ministry executive BN re: FPI glyphosate report, including proposed next steps and what, if any, communication strategy needs to be developed and deployed. To help on the latter piece I've invited Jeremy Uppenborn to join us. Also, attached is the last draft FPI report I have on hand along with a Cliff'ed version of the initial draft of the detailed summary BN I wrote/circulated yesterday (for background info only).

Hopefully we won't need the full hour, but I've blocked it just in case we do.

Ps. Shane's s.22 won't be joining us, but I've included him in the invitation so he can see what's going on.

Join online meeting

Trouble Joining? Try Skype Web App

Join by Phone

Local - Victoria: +1 (250) 952-9304,, s.15
Toll-Free: +1 (888) 952-9304, s.15
Local - Vancouver: +1 (604) 398-9304,, s.15
Find a local number

Conference ID: s.15

Forgot your dial-in PIN? | First online meeting?

Ministry of Forests, Lands, Natural Resource Operations and Rural Development

CLIFF: 252256
X-REF: 250351

BRIEFING NOTE FOR INFORMATION

DATE: November XX, 2019

PREPARED FOR: Diane Nicholls, Assistant Deputy Minister, Chief Forester, Minister of Forests, Lands, Natural Resource Operations and Rural Development

ISSUE: Summary of FPInnovations Glyphosate Review Report

BACKGROUND:

- Glyphosate is an herbicide used by the forest sector to reduce broadleaf competition with conifer plantations in order to accelerate the attainment of free-to-grow status.
- In spring 2019, the Office of the Chief Forester (OCF) initiated a review of glyphosate use in provincial forests to help inform future policy development and research needs.
- A small steering committee was established to define the scope/scale and oversee the review.
- FPInnovations (FPI) was awarded a $75,000[1] consulting services contract to assess current peer reviewed forest science and best practices related to glyphosate use in the context of, but not necessarily limited to:
    - The current value-set that applies to forest management throughout BC;
    - Where and why forest managers are still using glyphosate, how it relates to the current value-set (e.g., carbon, First Nations (FN), wildlife, and wildlife habitat, and alternative vegetation management approaches;
    - Document the uncertainties and assumptions related to forestry-related glyphosate use; and
    - How glyphosate use supports the overarching objective of promoting the establishment of healthy and diverse forests.
- This note provides a summary of highlights, key findings and recommendations set out in FPI's report. Subsequent notes will address potential next steps, including internal and external communication.

Deleted:)

HIGHLIGHTS, KEY FINDINGS AND RECOMMENDATIONS:

General/Background

s.13

- The effects of glyphosate on human health have been extensively reviewed by international regulatory agencies, including Health Canada, with the conclusion generally being that exposure to glyphosate does not pose a carcinogenic or genotoxic risk to humans.

s.13

[1] Subsequently increased to $82,500.

Draft

s.13

Regulation and Use

- Health Canada's Pest Management Regulatory Agency (PMRA) is responsible for regulating pesticide use in Canada. The PRMA re-approved glyphosate for use in Canada in 2017. After objections were raised regarding the re-approval the PRMA issued a supplementary statement in which it concluded that the objections could not be scientifically supported.
- The BC Ministry of Environment and Climate Change (ENV) regulates the sale and use of pesticides in BC under the Integrated Pest Management Act. Large scale use of pesticides requires the proponent to prepare and adhere to a Pest Management Plan.
- Notwithstanding its effectiveness as a silvicultural tool, glyphosate is also used to help manage invasive species. Of the 1,593 ha treated with herbicides for control of invasive species under the BC provincial jurisdictions of highways, forests and parks agencies, 8% of the area was treated using glyphosate.
- Data from this ministry's RESULTS shows that roughly 11,000 ha of Crown land was treated with glyphosate in 2018 with 86% sprayed aerially and 14% sprayed via ground-based methods. Most of the spraying of glyphosate occurred in the Omineca Natural Resource Region (73%) followed by the Northeast Region (11%). Smaller amounts of glyphosate use also occurred in the Thompson-Okanagan and South Coast Regions.
- In contrast to the agriculture and other common land uses where areas are sprayed repeatedly, glyphosate in forestry is typically applied once or occasionally twice in a rotation.
- Glyphosate treatments may target a wide variety of vegetation complexes ranging from grasses and herbaceous vegetation to shrubs and broadleaf species, but are most commonly used in the Sub-Boreal Spruce biogeoclimatic zone (targeting trembling aspen, mixed shrub, fireweed and wet alder).

Treatment Costs

- Glyphosate treatment costs vary widely, but are typically at least half that of manual methods (e.g., $300-$500/ha vs. $700-$1,200/ha). Costs of using manual methods vs. glyphosate for silviculture is currently estimated to $15M/yr exclusive of timber productivity loses.

Biodiversity

- One of the primary public concerns regarding the use of glyphosate in forestry is the perception that by using it to control competition of broadleaf species such as trembling aspen, broadleaves are being eliminated from the landscape. These claims are not supported when analysing the level of deciduous components at free-growing, or the increase in mixed deciduous stands over time as a result of forest management.
- A 2008 review of species diversity pre and post-harvest in BC found that the amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods. Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing, a 3,000% increase. Analysis further suggests that aspen stocking

Draft

recovers after glyphosate spraying and may in fact be increasing over time with forest management activities.

- Studies found that species richness and diversity of nontarget vascular plants was not negatively affected when measured 5-12 years after glyphosate application. Studies also found that while glyphosate reduced cover of herbaceous vegetation right after application, abundance and diversity recovered to pre-treatment levels as soon as one to two years after treatment. In many cases, herbaceous vegetation abundance, diversity and richness increased as a result of decreased dominance of the shrub and deciduous layer and recovery from the forest floor seed bank. Further, while glyphosate tends to result in a larger initial reduction of a wider range of species, brushing alternatives such as manual brushing has similar effects on plant communities, albeit at a higher treatment cost.
- Plants that survive glyphosate treatment may show altered phenotypes and metabolic actions due to the phytotoxcity of glyphosate and its breakdown product, aminomethylphosphonic acid (AMPA). New research findings suggest that these effects may persist for long periods, as glyphosate has been found to persist in low levels in some surviving perennial forest plants for at least 1 year. Glyphosate/AMPA residues were found primarily in root systems, as plants isolated glyphosate to resist mortality, however some translocation into shoots and fruit was observed in select plants.

Aquatic Organisms

- Amphibian populations are declining around the world and chemical contaminants released to aquatic environments have been listed as a threat. Studies have shown direct effects of chronic glyphosate exposures on fish, amphibians, invertebrates and other components of the ecosystem. However, field studies have not been able to replicate these toxicity effects under typical glyphosate application rates and conditions. Further, numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development, the expression of genes related to larval development, or juvenile amphibian survival. This is likely due to the short exposure duration and rapid sorption of the herbicide to sediment and other organic surfaces within the wetlands.
- A field study in coastal BC found temporary stress effects and minor mortality in caged Coho salmon smolt post glyphosate application. However, no acute mortality, changes in over-winter mortality, growth rate or change in use of the tributary were observed for resident Coho. Similarly, no effects on growth, behaviour or histopathology of gill and liver of resident rainbow trout were found after a two-month exposure of herbicide in a separate tank experiment. While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations in BC mandate the use of no-treatment pesticide-free zones around water features, dry streams and classified wetlands, further reducing the risk of negative effects on aquatic ecosystems.

Wildlife

- Several studies on the direct acute toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates. However, some uncertainty remains regarding the effects of long-term chronic exposure of low levels of glyphosate to wildlife through glyphosate persistence in forage.
- Moose populations have been declining in several regions of BC, and forage availability and quality has been flagged as a potential contributing cause to this decline.
- Glyphosate treatment has been found to reduce wildlife forage availability in the short term, reducing moose use of glyphosate-treated area for the first few years after treatment. However, the long-term impact of glyphosate use on habitat selection by moose is not well

understood. Further, some studies even show that by 7 to 11 years post treatment, moose seem to favour treated areas over controls although these impacts must also be considered in relation to the area treated annually and its distribution over the landscape. The effects of glyphosate's chelating properties on forage quality and nutrient availability are also poorly understood.

Soil and Water Quality

- Glyphosate is largely immobilized in the soil and then dissipates via microbial degradation. One of the compounds released during the microbial breakdown process – AMPA – is adsorbed to soils and biodegraded. However, AMPA is considered to be a mild phytotoxin with relatively unknown long-term consequences on soil organisms and plants.
- The mandated use of no-treatment pesticide-free zones around water features, the strong sorption to upper soil layers and the rapid uptake by plants minimize the risk of glyphosate entering aquatic ecosystems. Field studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken.

Climate Change

- Vegetation management can affect carbon sequestration due to its impact on structure and stand productivity. When used to control herbaceous or shrub vegetation for example, it allows the establishment of a woody crop delivering immediate carbon sequestration benefits in the woody biomass and coarse woody debris pools. When competing species are aspen or other deciduous species however, more carbon may be fixed by the stand if a deciduous component is left on site, although this effect varies with site and species.

Wildfire

- Fires in deciduous stands are usually slower moving surface fires which are easier to suppress than crown fires.
- The Canadian Forest Fire Behaviour Prediction system indicates that deciduous stands exhibit the least aggressive fire behaviour, followed by leafless deciduous or leaf-on mixed wood stands.
- Amongst deciduous trees, poplars show the most fire resistance. In one study, researchers estimate broadleaf forests to remain next to inflammable even as drought conditions worsen, in stark contrast to coniferous forests.
- The effect of fire behaviour from deciduous vegetation treated with glyphosate is not well documented. It is expected that the fire hazard in treated dead stems following treatment either manually or chemically would be very high.

First Nations

- Some FNs across BC have expressed concern over the use of glyphosate in forests related to plants that are traditionally gathered for food or medicinal purposes and which are killed directly by glyphosate or are considered contaminated.

s.13

Public Use

- Forest managers are faced with mounting public pressure over the safety of glyphosate use.
- Some recreational forest users are concerned about the application of glyphosate in the forest and its impacts to human health from being exposed to herbicides while hunting, fishing, berry

Draft

picking, mushroom picking, firewood cutting, camping or hiking. The Canada Pest Management Regulatory Agency's review on glyphosate has addressed many of these concerns and concluded that when used according to the label, glyphosate poses no risk to human health.

- There is currently no evidence that suggests that glyphosate application can cause game meat contamination, as glyphosate has not been shown to accumulate in animal tissues.
- Recent research on glyphosate persistence in some edible and medicinal plants and berries did find low yet unexpected levels of glyphosate, primarily localized in roots but sometimes found in shoot and fruit tissue.
- Better communication of the relevant science, including the persistence of low levels of glyphosate in some perennial forest plants, between forest managers and recreational users can help address key public concerns.

s.13

Timber Supply

- Vegetation control in some cases is necessary to supress competing vegetation and allow crop trees to become established and grow unimpeded. This unimpeded growth of conifers maximizes timber supply in the long term and the economic benefit derived from forests.
- Glyphosate is cost-effective vs. manual vegetation control methods.
- Relying on manual methods only for vegetation management would greatly increase reforestation costs and may result in an increase in non-satisfactorily restocked area with direct consequences on timber supply. This is compounded by the fact that some of the most productive growing sites are the most challenging to reforest due to brush competition.

Conclusions

s.13

- A review of current inventory data shows that stands that have been treated with glyphosate retain 15-21% deciduous components at free growing, and that the area comprised of deciduous-mixed stands has been increasing over time as a result of forest management activities in general.
- Field studies have shown that the risk of glyphosate and its metabolites on the environment is minimal when applied according to the label. Studies suggest that species richness and diversity of plant communities, small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes to communities tend to be transient.
- Some knowledge gaps were identified in the literature, specifically pertaining to poorly understood effects on soil microorganisms, glyphosate's chelating effects on soil and plant nutrients, and glyphosate persistence in plants that survive treatment. More research is still needed to understand some of the more nuanced impacts glyphosate may have at the site level. Forest managers must recognize and manage for these uncertainties. Better communication of current practices, research findings, and known sources of uncertainty regarding the use of glyphosate in forests is also needed.
- While more research is recommended on the identified knowledge gaps, the use of glyphosate needs to be further considered within the context of the amount of area treated, the short time

scale of site-level effects, and the mosaic of treated and non-treated areas that exist at the stand- and landscape-levels. Many of the public's concerns and challenges faced by our forests today, such as increasing wildfire risk and declining moose populations, can be better served by better linkages between site and landscape level planning that allow other non-timber values to be prioritized where needed.

Recommendations

s.13

Attachments: FPI Report – Review of Glyphosate Use in BC Forestry (Nov. 2019)

PREPARED BY:

Shawn Hedges, RPF
Director, Sustainability and Forestry
Office of the Chief Forester
(250) 896-9911

REVIEWED BY:

	Initials	Date
ADM	DN	
ED	SB	
Program Dir/Mgr.	SH	

Schedule A - Services

File: 1070-20/FH20FHQ067

Attachment to the Agreement with FP Innovations for Glyphosate Policy Review for the Office of the Chief Forester, Assistant Deputy Minister Office.

1. THE SERVICES

1.01 The Contractor shall provide the following Services:

(a) Undertake an analysis of current peer reviewed forest science and best practices related to glyphosate use in the context of, but not necessarily limited to, the following:

i. The current value-set that applies to forest management throughout provincial forests (e.g., biodiversity, carbon, wildfire, natural range in variation of all species – not just conifers – First Nations and public use);

ii. Where and why forest managers are still using glyphosate, how it fits in relative to the values set out in (i.) above, and alternative vegetation management approaches?

iii. Uncertainties and assumptions related to forestry-related glyphosate use; and

iv. The overarching objective outcome of promoting the establishment of healthy and diverse forests.

(b) Additional focus areas assigned by the Glyphosate Policy Review Steering Committee may be included provided any increases in project scope correspond with an increased budget to cover additional costs.

(c) Will participate in regularly scheduled meetings (e.g., monthly) to discuss progress of work and resolve emerging issues.

1.02 Outcomes:

(a) Through the delivery of the Services the Province wishes to realize the following outcomes and, without limiting the obligation of the Contractor to comply with other provisions of this Part, the Contractor must use commercially reasonable efforts to achieve them:

- A single report that sets out the findings of the work set out in s. 1.01 and includes a guidance document related to general recommendations, recommended best practices and a compendium of key/noteworthy information and references supporting the report and guidance material.

The parties acknowledge that the Contractor does not warrant that these outcomes will be achieved

2. KEY PERSONNEL

2.01 The Services shall be performed by the following "Key Personnel":

(a) James Hunt, Lead Scientist

(b) Pamela Matute, Researcher

(c) Ken Byrne, Manager

(d) Yvonne Chu, Communications Coordinator

and there shall be no substitution for the person(s) listed above without the prior consent of the Province.

Ministry of Forests, Lands, Natural Resource Operations & Rural Development

Schedule B – Contract Payment

File: 1070-20/FH20FHQ067

Attachment to the Agreement with FP Innovations for Glyphosate Policy Review for the Office of the Chief Forester, Assistant Deputy Minister Office.

1. Fees

1.01 Your fees (**exclusive of any applicable taxes described in this Agreement that is a taxable transaction chargeable to the Province**) will be based on rates of s.17; s.21
s.17; s.21

1.02 In no event will **fees** payable to you in accordance with this Schedule exceed in total $70,000.

2. Expenses

2.01 We will pay you the following expenses exclusive of goods and services tax ("GST") or other applicable tax paid or payable by you to the extent that you are entitled to claim credits (including GST input tax credits), rebates, refunds or remissions of the tax from the relevant taxation authorities and provided they are:

(a) supported, where applicable, by proper receipts or copies of receipts;

(b) in our opinion, necessarily incurred by you in providing the Services; and

(c) payable in accordance with our policies and attached "Travel Expenses Payable to Service Contractors", forming an integral part of this Agreement:

(i) travel, accommodation and meal expenses for travel greater than 32 kilometres away from FPInnovations 2665 East Mall, Vancouver, British Columbia.

(ii) actual long-distance telephone, facsimile, courier, postage and other identifiable communication expenses.

2.02 In no event will **expenses** payable to you, in accordance with this Schedule, exceed, in total: $5,000.

3. Total Payable

3.01 In no event will the Total Payable for fees and, where applicable, expenses (exclusive of any applicable taxes described in the Agreement) in accordance with this Schedule exceed in total $75,000.

4. Holdback from Payment

4.01 As per the Agreement, the Province does not intend to retain a holdback from contract payments but the Province does retain the right to withhold from any payments due to you under this Agreement an amount sufficient to indemnify us against any third-party claims.

SCHEDULE B

CONTRACT PAYMENT

5. Submission of Statement of Account

5.01 In order to obtain payment for any fees and, where applicable, expenses under the Agreement, you must submit to us a written Statement of Account in a form satisfactory to us on a quarterly basis.

5.02 The Statement of Account(s) must show the following:

(a) your legal name, address, the date and the period of time which the invoice applies ("Billing Period"), the contract number, and a statement number for identification;

(b) the calculation of all fees claimed under this Agreement for the Billing Period, with hours, dates, rates, and name(s) of persons providing the Services, a description of specific services/works completed during the Billing Period, including a declaration that the Services have been completed;

(c) and where expenses are to be paid under this Agreement, a chronological listing, in reasonable detail and with dates, of all expenses claimed by you under this Agreement for the Billing Period with receipts or copies of receipts, where applicable, attached;

(d) if you are claiming reimbursement of any GST or other applicable taxes paid or payable by you in relation to those expenses, a description of any credits, rebates, refunds, or remissions you are entitled to from the relevant taxation authorities in relation to those taxes;

(e) the calculation of any applicable taxes payable by us in relation to the Services provided under this Agreement and for the Billing Period as a separate line item (excluding taxes paid directly by you to a supplier and which were included in the bid price);

(f) any other billing information reasonably requested by us.

5.03 Within thirty days of our receipt of your invoice, or the date we authorize payment, whichever is the latter, we must pay you fees and, where applicable, expenses for those Services we determined were satisfactorily received during the Billing Period.

5.04 Invoices are to be submitted to:

Via email c/o Shawn Hedges, Director, Sustainability and Forestry at Shawn.Hedges@gov.bc.ca

5.05 The **Expenses Claim Form** is the recommended format for claiming expenses on your invoice. You can obtain a copy of the Expenses Claim Form from the ministry if one has not been provided.

Natural Resource Sector

Schedule C
Safety Conditions

File: 1070-20/FH20FHQ067

Attachment to the Agreement with FP Innovations for Glyphosate Policy Review for the Office of the Chief Forester, Assistant Deputy Minister Office.

Terms such as "employer", "supervisor", "multiple employer workplace", "owner", "prime contractor", and "worker" have the meanings given those terms under the *Workers' Compensation Act* (*WC Act*) and its regulation.

ARTICLE 1 OTHER SAFETY CONSIDERATIONS

Notice of Project

1.01 Where a Notice of Project is required as set out in the *WC Act* and its regulations, the Contractor, unless otherwise notified in writing by the Province or the Prime Contractor, must submit the Notice of Project in a format acceptable to WorkSafe BC.

1.02 Where the Contractor submits the Notice of Project, a copy must be provided to the Province. Where the Province or Prime Contractor will submit the Notice of Project, the Contractor must provide, upon request, all information necessary to support the Notice of Project and the Contractor will be provided with a copy of the Notice of Project.

1.03 The Contractor will commence and conduct all operations consistently with the Notice of Project.

Reporting

1.04 The Contractor must immediately submit written notice to the Province on all matters reported to WorkSafe BC by the Contractor or the Contractor's Subcontractors. The written notice must include all information necessary to allow the Province to adequately collect and address safety or other related incidences, and will be anonymized so as not to include personal information about an identifiable individual including their name, address, telephone number, age, sex, race, religion, sexual orientation, disability, fingerprints, or blood type, health care, educational, financial or employment history and anyone else's opinion about the individual. This scope does not include business contact information (e.g., name, title, address, telephone or fax numbers or email address used for business contact purposes).

1.05 Where a Party brings safety concerns to the attention of the other Party, the Party will give full consideration to the issues raised. Where the Contractor receives safety concerns from the Province, the Contractor will provide the Province with a considered response, including any information necessary to demonstrate that the Contractor is in compliance with *WC Act* and its regulations.

1.06 Upon the Province's request, the Contractor or any of its Subcontractors must provide evidence to the satisfaction of the Province that the Contractor or its Subcontractor(s) has:

(a) an effective business process in place to:

i) remedy any workplace conditions that are hazardous to the health or safety of the employer's workers including safe work practices and procedures;

ii) ensure that the employer's workers:

A. are made aware of all known or reasonably foreseeable health or safety hazards to which they are likely to be exposed by their work;

B. are made aware of their rights and duties under the *WC Act* and its regulations.

(b) established occupational health and safety policies and programs in accordance with the regulations, which includes:

i) first aid assessment and provision services and equipment;

ii) an employee monitoring system that will periodically ensure the well being of all workers working alone or in isolation;

iii) accident injury reporting and investigation;

iv) an emergency response plan and employee understanding of said plan that will ensure adequate and timely response to any emergency that can be reasonably expected to occur in relation to the Works or Services being performed;

v) evidence of training and any required certifications required under *WC Act* or its regulations;

vi) evidence of a maintenance program for all equipment and vehicles owned or operated by the Contractor or its Subcontractors commensurate with the risks associated with such equipment and vehicles;

vii) provision for the regular inspection of premises, work methods and work practices; and

viii) provision by the employer for the instruction and supervision of workers including orientation of workers in the safe performance of their work.

(c) provided and maintained in good condition protective equipment, devices, and clothing as required by the *Occupational Health and Safety Regulation* and ensure that these are used by the employer's workers;

(d) provided the employer's workers all information, instruction, training, and supervision necessary to ensure the health and safety of those workers in carrying out their work and to ensure the health and safety of other workers at the workplace;

(e) a copy of the *WC Act* and its regulations readily available for review by the employer's workers and, at each workplace where workers of the employer are regularly employed, post and keep posted a notice advising where the copy is available for review.

ARTICLE 2 PRIME CONTRACTOR PROVISIONS

2.01 The Contractor acknowledges, agrees, and warrants that:

(a) The Contractor will be considered to be the Prime Contractor and shall enter into a Prime Contractor Agreement with the Province and shall carry out the duties described therein, where any of the following conditions exist:

(i) the Province gave notice that the Successful Bidder would be the Prime Contractor;

(ii) the Province designates the Contractor to be the Prime Contractor at any time during the performance of the Work or Services;

(iii) the Contractor creates a multiple employer workplace through subcontracting any of the Work or Service at any time.

2.02 Where the Contractor is being considered as the Prime Contractor as per clause 2.01, the following is applicable:

(a) upon request, the Contractor must satisfy the Province that the Contractor has the experience and capacity to address Prime Contractor responsibilities in accordance with the Agreement and the WC Act and its regulations; and

(b) the Province provides written acknowledgement of the Contractor's experience and capacity to function as Prime Contractor; and

(c) where the Contractor creates a multiple employer workplace, the Contractor will provide or acquire at their own expense all resources necessary to discharge the Prime Contractor responsibilities; or

(d) the Province may, in its sole discretion, give consideration for compensation related to any

additional costs where, after commencement of the work, the Province creates a multiple employer workplace and designates the Contractor to be the Prime Contractor.

2.03 The Province may from time to time give prior written notice that a person other than the Contractor is designated as the Prime Contractor. The Contractor agrees that on receiving such written notice, the Contractor will cooperate with the Prime Contractor and shall coordinate health and safety activities and ensure compliance with the Prime Contractor's safety program.

2.04 The Contractor shall, upon becoming aware of any apparent deficiencies in the Prime Contractor's work which would affect the Work or Services, shall report such deficiencies in writing to the Ministry Representative.

Natural Resource Ministries

Schedule D – Insurance

File: 1070-20/FH20FHQ067

Attachment to the Agreement with FP Innovations for Glyphosate Policy Review for the Office of the Chief Forester, Assistant Deputy Minister Office.

1. Without restricting the generality of the indemnification provisions contained in the Agreement, the Contractor shall, at its own expense, provide and maintain, during the term of this Agreement, the following insurance coverage as fully specified in Paragraph 12 and any additional insurance which it is required by law to carry or which it considers necessary to cover risks not otherwise covered by insurance specified in this Schedule in its sole discretion.
2. All such insurance described herein must be primary and not require the sharing of any loss by any insurer of the Province.
3. Where a warranty period is required by the Province under this Agreement, the Contractor shall ensure that Products and Completed Operations coverage, as applicable, shall be in force for the duration of the warranty period.
4. Insurance shall be placed with Insurers licensed to underwrite such insurance in Canada and in forms and amounts acceptable to the Province. All such insurance shall be at no expense to the Province. If the Province requires additional Insurance Coverage to be obtained by the Contractor, the additional expense of such additional insurance shall be borne by the Province.
5. Notwithstanding Paragraph 6, the Contractor shall, prior to the commencement of services and before any payments are made under this Agreement, file with the Ministry Representative evidence of insurance coverage in the form of a completed Province of British Columbia Certificate of Insurance (Form FIN 173). When requested by the Province, the Contractor shall provide certified copies of required insurance policies.
6. ICBC's Confirmation of Automobile Insurance Coverage (Form APV 47) or Confirmation of Unlicensed Vehicle Coverage (Form APV 45) may be used when applicable as evidence of Automobile Liability Insurance for vehicles or off-road vehicles used during the performance of the services.
7. The insurance policies, except for ICBC Automobile Liability Insurance, shall provide that the insurance shall not be cancelled or materially changed so as to affect the coverage provided under the Agreement, without the Insurer giving at least thirty (30) days prior written notice to the Province. Material change with respect to Professional Liability Insurance does not require the Insurer to give thirty (30) days prior written notice to the Province.
8. Failure to provide the required insurance documentation shall result in termination of this Agreement.
9. If the insurance policies expire prior to the end of the Agreement Term, the Contractor shall provide the ministry evidence of renewal or new policy meeting the requirements of the expired insurance in the form of a completed Province of British Columbia Certificate of Insurance and ICBC's Form APV 47 or APV45, if applicable, at least ten (10) days prior to the expiry date of the policies listed in this Schedule.
10. The Contractor shall ensure that all its subcontractors performing Services under this Agreement carry insurance in the form and limits specified in Paragraph 12.

11. Unless stated otherwise under any subsection of Paragraph 12, where the Province is to be added as an Additional Insured or otherwise to be identified on the policy, it shall be written as follows: "Her Majesty the Queen in right of the Province of British Columbia as represented by the Minister of Insert Ministry Name and any of its employees, servants or agents".

12. The following forms of insurance and specified minimum limits are required:

a) **Commercial General Liability**

Commercial General Liability insurance in an amount not less than $2 million inclusive per occurrence against bodily injury, personal injury, and property damage and including liability assumed under the Agreement.

Such policy(s) of insurance shall include, but not be limited to:

i) Products and Completed Operations Liability;
ii) Owner's and Contractor's Protective Liability;
iii) Contingent Employer's Liability;
iv) Blanket Written Contractual Liability;
v) Personal Injury Liability;
vi) Non-Owned Automobile Liability;
vii) Cross Liability;
viii) Employees as Additional Insureds;
ix) Broad Form Property Damage;

and where such further risk exists:

x) Forest Fire Fighting Expense Coverage in the amount of:
- ☐ $1 million
- ☐ $500,000
- ☒ Not applicable

xi) Sudden and Accidental Pollution endorsement on the Commercial General liability insurance policy with a limit of liability not less than the amount indicated below per occurrence insuring against bodily injury, property damage and clean-up expenses arising from new pollution conditions arising from the Contractor's performance of the Agreement, or if such endorsement is unavailable on the Commercial General Liability insurance policy, a Sudden and Accidental Pollution insurance policy insuring against same and with same limits of liability indicated below, such policy shall not contain an "insured vs insured" exclusion and this insurance shall include the Province as an additional insured as stated below:
- ☐ $250,000
- ☐ $500,000
- ☐ $1 million
- ☒ Not applicable

As per Paragraph 11, the Province is to be added as an "Additional Insured" under this policy.

b) **Automobile Liability**

Where any licensed vehicle or off road vehicle is owned, leased, rented, or used in the performance of this Agreement, Third Party Automobile Liability insurance in an amount not less than $2 million inclusive per occurrence must be provided for any such vehicle.

GLYPHOSATE POLICY REVIEW STEERING COMMITTEE - TERMS OF REFERENCE

ROLE/PURPOSE

The Glyphosate Policy Review Steering Committee (GPRSC) is responsible defining the scope and scale of the policy review of glyphosate use in BC's provincial forests. The GPRSC is also responsible for overseeing and steering the process by which the policy review will occur, including issue resolution, seeking higher level approval or endorsement as required (e.g., Chief Forester, Deputy Minister etc.) and developing and deploying guidance, new policy and other ancillary products.

TERM

The term of the GPRSC coincide with the duration of time it takes to fulfill the mandate set out above – estimated to be 12 months – but may be extended or shortened as approved by the Chief Forester.

MEMBERSHIP

Julie MacDougall, Director, Resource Practices Branch, FLNRORD – Co-Chair	Shawn Hedges, Director, Sustainability & Forestry, FLNRORD – Co-Chair
Lorne Bedford, Manager, Harvesting & Silviculture Practices, FLNRORD	Neil Hughes, Forest Establishment Leader, FLNRORD
Jennifer Psyllakis, Director, Wildlife & Habitat, FLNRORD	Christa Zacharias-Homer, Director, Environmental Standards, MOE

GOVERNANCE/DECISION-MAKING

The preferred form of decision-making in respect of matters pertaining to the GPRSC will be consensus-based (i.e., general agreement). If consensus isn't possible, the matter will be deferred pending further analysis and discussion, or referred to the committee co-chairs for resolution.

WORKING METHODS

The GPRSC will use a variety of working methods including but not limited to, working independently or in group settings.

Depending on the nature of the work/issues being discussed, meetings will include periodic one-on-one phone calls, conference calls and web-based (e.g., Skype) and in-person meetings.

AMENDMENT, MODIFICATION OR VARIATION

These terms of reference may be altered/amended if/as necessary with the endorsement of the co-chairs or at the direction of the Chief Forester.

BUDGET

To be confirmed.

RESOURCES

Meeting rooms and ancillary expenses and external services will be covered by the Office of the Chief Forester.

Business travel, if necessary, will be the covered by the GPRSC base responsibility centre.

Natural Resource Ministries

Travel Expenses Payable to Service Contractors - Attachment to Schedule B

File: 1070-20/FH20FHQ067

Attachment to the Agreement with FP Innovations for Glyphosate Policy Review for the Office of the Chief Forester, Assistant Deputy Minister Office.

General: "Travel Status" means travel necessarily incurred by you in the performance of the Services in British Columbia and that is pre-approved by the ministry. Travel Status begins and ends at the locations and distance designated in the Contract Payment Schedule.

Travel not meeting the description of 'Travel Status', must be approved by the ministry and written into the contract before the additional travel expense will be reimbursed.

The most economic travel arrangements should be used consistent with the time available to conduct the business.

Travel expenses must not be billed directly to the province by the contractor.

Notwithstanding your status as an independent contractor, expenses incurred on out-of-province travel will only be reimbursed when specific provision is made in the contract and prior approval for the travel has been obtained from the ministry.

Contractors will be provided with a Letter of Authorization for Cost Recoverable Contractors for vehicle rental and/or hotel accommodations.

Meals: Meals received at public expense or without charge may not be claimed. On the date of departure, travel status must start before 7:00 a.m. to claim breakfast; before 12:00 noon to claim lunch; and, on the date of return, travel status must end after 6:00 p.m. to claim dinner. Meal and per diem allowances **effective April 1, 2018** are as follows:

Breakfast Only	Lunch Only	Dinner Only	Maximum Full Day	B & L Only	L & D Only	B & D Only
$12.00	$14.00	$24.00	$50.00	$26.00	$38.00	$36.00

Private Vehicle Use: $0.54 per kilometre [applicable only when driving beyond 32 kilometres from the Base Location(s) indicated in Schedule B].

Rented Vehicle Use*: Cost of rented vehicles may be claimed, if required in order to perform the Services and if approved by the Province.

Upon request and in advance of any rental, the Province will provide an authorization letter for access to the government's Corporate Supply Arrangement (CSA). These CSAs entitle government authorized contractors to preferred vehicle rental rates.

- Approved car rental agencies and the maximum rates for each community are listed at Vendors by location.

Other agencies are to be used only when these agencies cannot supply vehicles or when renting a vehicle outside BC.

Personal Accident Liability (PAL) will not be reimbursed. Collision Damage Waivers (CDW) will be reimbursed only when renting from a company not on the approved list for a specific community or when renting outside BC.

Accommodation*: Acquisition of hotel accommodation will be made using the guide located at http://csa.pss.gov.bc.ca/businesstravel/. The initial sort in the guide is by city, then alphabetically by hotel name. Click on the hotel name to link to the pricing details for that hotel.

In making a hotel selection for your travel, you must select the most cost effective hotel that meets your business requirements considering the basic room cost and any supplementary costs for internet access, parking or other costs.

You must ensure the price you are charged is at or below the rates quoted in the hotel guide for the room and any supplementary charges (there may be specials or promotional prices that are below the rates quoted in the guide). The 'number in party" identified on the receipt must show only one person.

Only in exceptional or emergency circumstances should a hotel be used that is not in the guide – ie. all the hotels in the guide are full. Before using another hotel, you must obtain the pre-approval of the Ministry Representative.

Where private accommodation is used, a maximum of $31.65 per day is payable - no receipts required.

Parking*: When a vehicle is utilized by a contractor while engaged in the fulfillment of his/her obligations under the Agreement, receipted parking charges will be reimbursed at cost.

Ferry Travel*: Full cost of passenger and/or vehicle ferry travel will be reimbursed. Receipts or legible copies are required. Costs of using private boats are not reimbursable.

Air Travel*: Cost of economy class fare is payable when the passenger copy of the air ticket (or a legible copy) is submitted - a requirement even when fare is paid through a travel agency.

Highway Tolls*: Full cost of highway tolls can be claimed.

Bus/Taxi Costs:** Travel by bus or taxi costs when traveling point-to-point will be reimbursed. Receipts are not required, unless daily charges are in excess of $20.00.

Business Long Distance Telephone, Postage, Facsimile, Courier and other legitimate communication expenses incurred as part of the Agreement are reimbursable when detailed by invoice or statement. Expenses where receipts have been issued, (e.g. courier expenses, telephone) receipts or legible copies must be submitted as substantiation.

Miscellaneous Travel Expenses: Laundry, gratuities, porterage and personal phones calls cannot be claimed.

*** Expense receipts or legible copies must be submitted.**

****Receipts or legible copies must be submitted if expense in excess of $20.00 per day.**

The following general comments are in response to my reading of a recent draft of GLYPHOSATE USE IN BC FORESTRY – REVIEW AND BEST PRACTICES by Jim Hunt and Pamela Matute, FPInnovations. I trust this will support the improvement of future drafts of this important and timely review. Comments are solely my own, and I advise the reader to consider the veracity of my claims and opinions against empirical information provided by the literature.

Regards,

Jeffery R. Werner
Wildlife Ecologist, FLNRORD
September 25 2019

s.13

Page 432 of 434 to/à Page 434 of 434

Withheld pursuant to/removed as

s.13