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REVIEW OF GLYPHOSATE USE IN BRITISH COLUMBIA FORESTRY

PROJECT NUMBER: 301013763

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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.

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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.

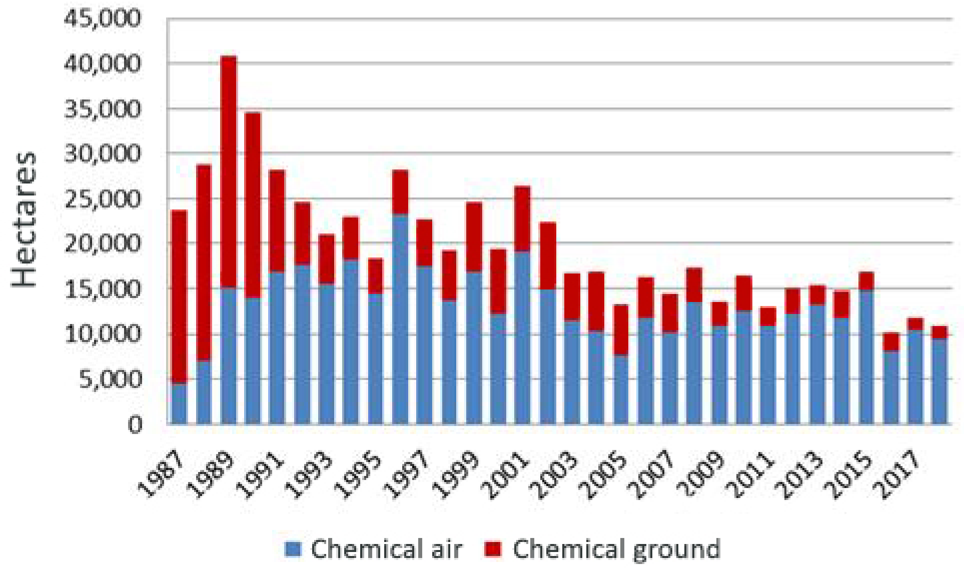

Figure 1. Area sprayed with glyphosate for silviculture in British Columbia.

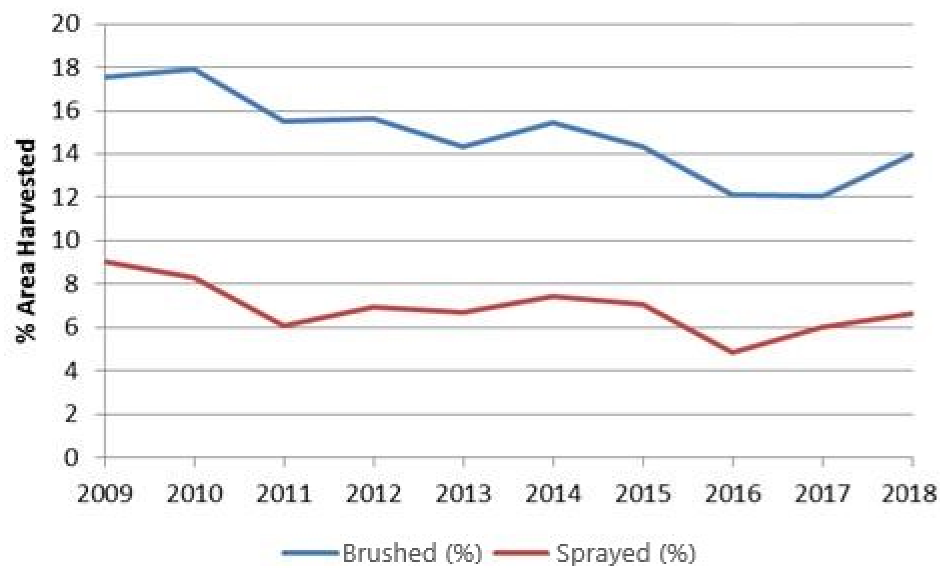

Figure 2. The percentage of harvested area that was brushed using alternative methods and sprayed with glyphosate.

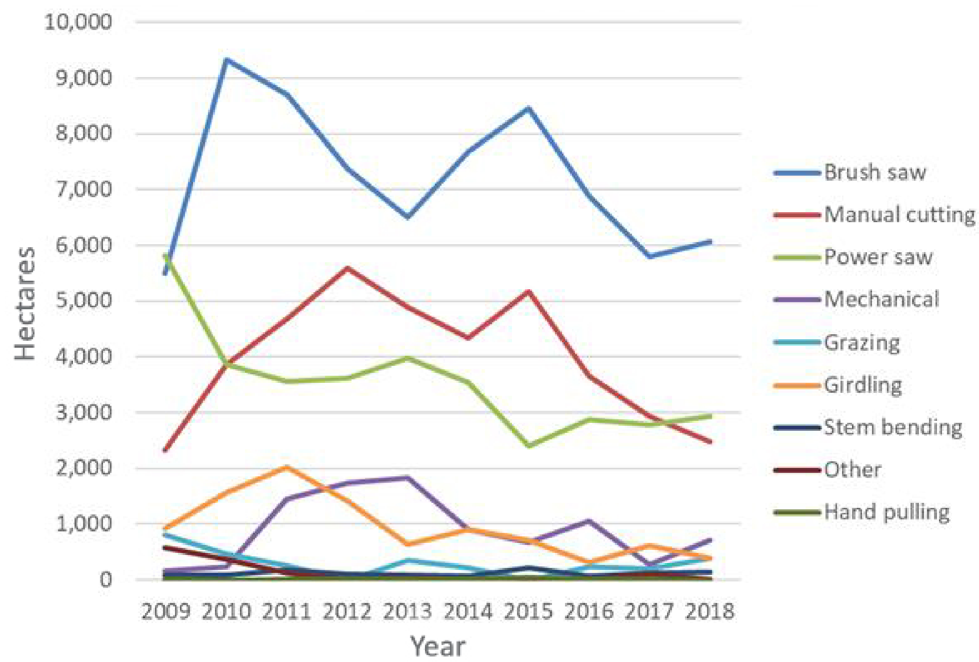

Figure 3. Area brushed using non-chemical methods.

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**

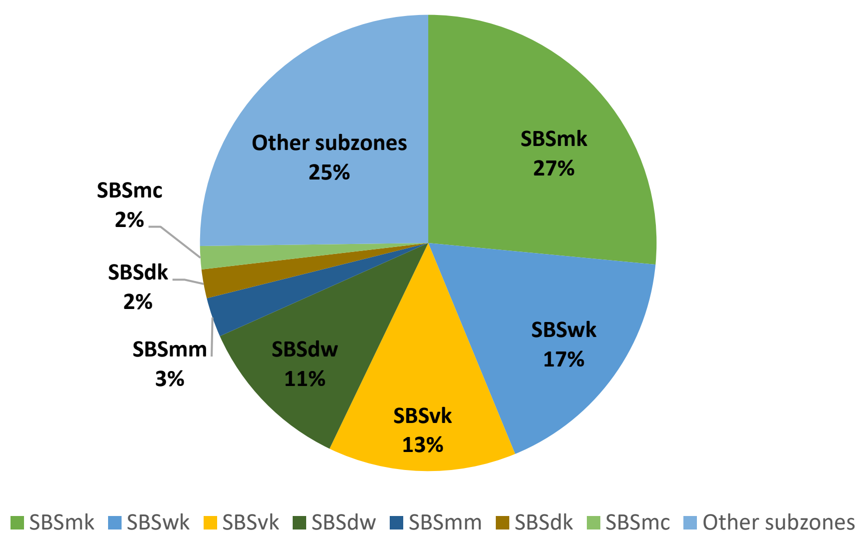

Figure 4. Herbicide use by biogeoclimatic subzone. (SBS: Sub-Boreal Spruce, mk: moist cook, wk: wet cool, vk: very wet cool, dw: dry warm, mm: moist mild, dk: dry cool)

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.

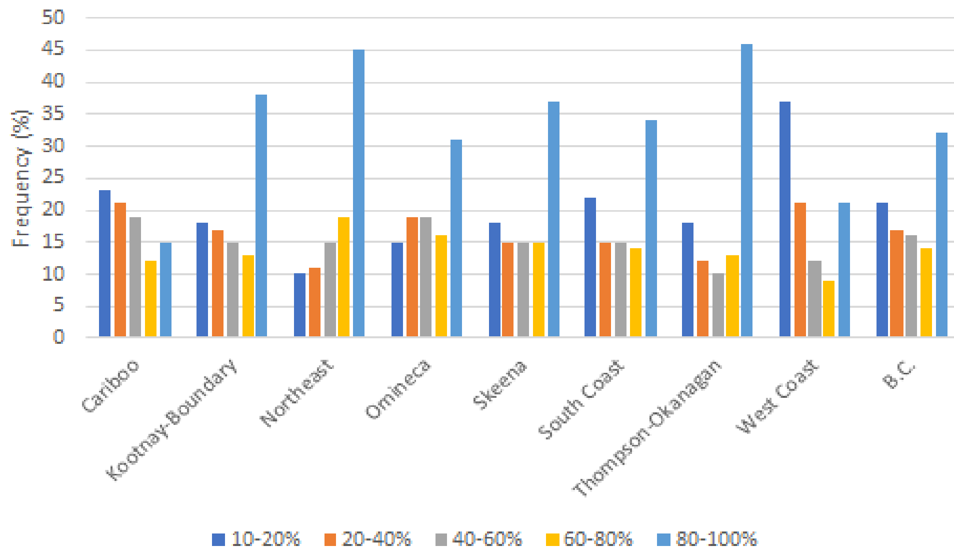

Figure 5. Distribution of the percentage of area treated with glyphosate within the net area to be reforested in a block, since 1998. Data is for one-time treatments only.

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

- More research is needed to fully understand the extent of some environmental impacts of glyphosate use. Impacts on soil microorganisms, for example, are variable and poorly understood. Likewise, further research is needed on how long glyphosate can persist in plants and whether that has effects on wildlife forage nutritional quality. Preliminary research suggests that persistence in plants is related to climate and ecology, and that it may be possible to develop tools to assess the level of persistence.
- Province-wide detailed data on which specific vegetation complexes are targeted by glyphosate and in which proportions would provide a clearer picture of its impacts on multiple values. This gap also needs to be addressed in order to understand potential timber supply impacts of foregoing herbicide use because many important vegetation complexes such as grasses cannot be controlled effectively by manual methods.
- The level at which vegetation management affects the risk of wildfire is not clearly understood. More data are needed to update fire behaviour models, which could influence vegetation management to reduce wildfire risk.
- While RESULTS data show that the use of glyphosate does not result in the elimination of broadleaf components from sprayed stands, further monitoring of broadleaf components and their spatial distribution after free growing would provide an improved understanding of how vegetation management impacts objectives such as biodiversity, and carbon sequestration. This would also provide some indication of the effectiveness of brushing programs and if reductions in herbicide use are impacting conifer productivity.
- Better communication between forest managers and the public about the relevant science, current practices and the rationale behind vegetation management is needed to help address key public concerns and rebuild trust. Similarly, proactive engagement with First Nations can often resolve issues. An understanding can often be reached through relationship building, education, listening to concerns, and collaborative problem-solving.
- Stakeholders have expressed that clearer objectives and guidance around managing deciduous components are needed. Where timber production is a key management objective, studies have shown that glyphosate use is effective for maintaining forest productivity with minimal and transient impacts on the environment. Where non-timber objectives are identified as priorities, stakeholders have indicated that more flexibility and better guidance and support for alternative stocking standards could facilitate reduced brushing and glyphosate use and accommodate other values.

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.

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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

- 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

Limitations

- 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

- 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

Limitations

- 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

- 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

Limitations

- 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

- No herbicide use
- Public acceptance
- Increased soil temperature
- Facilitates planting

Limitations

- Expensive
- Access and soil disturbance
- Site constraints—trafficability
- 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

- No herbicide use
- Good seedbed, plantable spots

Limitations

- Expensive
- 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

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