GLYPHOSATE USE IN BC FORESTRY - REVIEW AND BEST PRACTICES

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1 Introduction

Successful regeneration after harvest often requires control of competing vegetation which may cause mortality or reduced growth of established seedlings. Glyphosate-based herbicides are the most widely used in the world, largely due to their effectiveness and the development of glyphosate tolerant crops (Edge et al 2014). Several factors contribute to the use of this active ingredient:

- 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,
- Minimal impact on forest ecosystems (Rolando et al 2017).

Public pressure to reduce the use of glyphosates has been increasing in British Columbia and other jurisdictions. This report reviews scientific literature and best practices and considers glyphosate use in relation to the set values pertinent to forest management in BC. This report focuses on glyphosate application for silviculture as a vegetation management tool. Issues around glyphosate use also relate to larger issues concerning vegetation management and forest management.

The effects of glyphosate on human health have been extensively reviewed by regulatory agencies including Health Canada Pest Management Regulatory Agency (PMRA) which are summarized in Appendix 1. The report scope does not include glyphosate application for agriculture, transmission or transportation corridors, or other industrial uses.

The Canadian Forest Service provides an overview on Canadian herbicide use in forestry with detailed responses to frequently asked questions[1].

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[1] http://forestinfo.ca/faqs/

2 Use of Glyphosate in BC Forests

2.2 Regulatory Framework

2.2.1 Herbicides

Health Canada's Pest Management Regulatory Agency (PMRA)[2] is responsible for pesticide regulation in Canada. Pesticides are regulated in Canada to ensure they pose minimal risk to human health and the environment. Under authority of the Pest Control Products Act, Health Canada:

- registers pesticides after a stringent, science-based evaluation that ensures any risks are acceptable;
- re-evaluates the pesticides currently on the market on a 15-year cycle to ensure the products meet current scientific standards (latest review was in 2017); and
- promotes sustainable pest management.

In B.C., the Integrated Pest Management Act and Regulation[3] set out the requirements for the use and sale of pesticides in 2004. The B.C. Ministry of the Environment promotes Integrated Pest Management (IPM) and environmental stewardship and ensures compliance with the IPM Act and Regulations. Large scale programs (>20 ha/year) that require IPM must have a Pest Management Plan (PMP) and a Pesticide Use Notice of Confirmation. PMPs document how IPM will be implemented and indicate standards for consultation, notification, reporting and herbicide handling and application, as well as alternatives to using herbicides. Detailed site assessment surveys describe the technical detail supporting herbicide prescriptions.

The Act defines IPM as "a process for managing pest populations"[4]. In a forestry context where competing vegetation is considered as a pest or weed, following IPM elements would apply:

- Planning and managing ecosystems to prevent organisms from becoming weeds;
- Identifying weed problems and potential weed problems;
- Monitoring populations of weeds and weed complexes;
- Using injury thresholds in making treatment decisions;
- Select pest treatment methods based on:
    - Consideration of practical alternatives to herbicide use,

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[2] https://www.canada.ca/en/health-canada/corporate/about-health-canada/branches-agencies/pest-management-regulatory-agency.html
[3] https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management/pesticide-use/regulations-consultations
[4] https://www2.gov.bc.ca/assets/gov/environment/pesticides-and-pest-management/business-and-industry/forestry_review.pdf

  - Protection of human health and the environment; and

- Evaluating the effectiveness of weed management treatments.

Best practices for implementing integrated vegetation management are included in Appendix 2 which summarizes selected PMPs.

2.2.2 Free Growing

Timber harvesting in B.C. is regulated such that any harvested area has to be reforested to an acceptable standard of free growing. The Forest Range and Practices Act[5](FRPA), (sec 1) defines "free growing stand" 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*".

The supporting Forest Planning and Practice Regulation[6] (FPPR) (sec 44) addresses obligations to produce a free growing stand that meets applicable stocking standards approved in a Forest Stewardship Plan (FSP) by applicable dates. Stocking standards refer to regeneration requirements such as suitable species, stand density, spacing, free growing height and ratio of crop to competition, that a stand is required to be regenerated to in order to comply with large-scale objectives for the landbase. These are set out in the licensee's FSP and approved by the District Manager. Sec 46.11 indicates that the obligation must be fulfilled on each ha within the net area to be reforested, unless otherwise specified in a FSP. Mappable areas that do not meet stocking standards should not exceed 2 ha or 5% of the Standard Unit (SU) area. Under FPPR section 97.1, an obligation holder may be relieved of the obligation to meet stocking standards if obligations have been met to the extent that is practicable.

FPPR section 26 (5) provides a mechanism to develop stocking standards in an FSP that are not consistent with current timber supply assumptions. The review test for section 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.

Survey standards for quantifying shrub and broadleaf competition relative to free growing definitions are described in the Silviculture Surveys Procedures Manual[7]

The best management practices allowing for expanded management of broadleaf resources on the landscape have evolved since the 1990s and are described in Appendix 2.

2.2.3 Invasive Species

FRPA sec 47 indicates that a person carrying out a forest or range practice must carry out measures to prevent the introduction or spread of prescribed species of invasive plants as listed in the invasive species regulation. The BC Weed Control Act requires all land occupiers to control the spread of noxious weeds on their land or premises.

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5 http://www.bclaws.ca/Recon/document/ID/freeside/00_02069_01

6 http://www.bclaws.ca/civix/document/id/lc/statreg/14_2004

7 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/silviculture-surveys/silviculture_surveys_procedures_manual_2018.pdf

While the focus of this report is the use of glyphosate in BC silviculture, the importance of glyphosate for controlling noxious weeds cannot be understated. [*Crystal Chadburn MOE to provide references Sept 10*]. Japanese knotweed, giant hogweed and other invasive plants can significantly impact ecological and infrastructure values. Manual treatments are not effective as Japanese knotweed can resprout from small plant fragments. Chemical treatment that translocates within target invasive plants is the best option for killing noxious weeds. Glyphosate is the only effective treatment available for treating knotweed within 10 m of a watercourse, where the need for control is greatest. Any constraint on the use of glyphosate for controlling knotweed and other noxious weeds would result in greater proliferation of noxious weeds.

2.3 Why is Glyphosate Used?

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

- to prevent plantation mortality from aggressive competition, and
- to meet free growing obligations that ensure crop tree productivity.

Glyphosate is one of many vegetation management tools available to forester managers. It is very effective because it is easily translocated within the target plant, usually killing it, and reducing the brush hazard for multiple years after a single application.

In contrast, manual vegetation control treatments generally provide only short-term relief from competing vegetation with control often lasting only for the balance of the growing season during 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 controlling cover sufficiently to benefit seedling growth for more than a few years (Harper et al. 1997a, b; 1998; Whitehead and Harper 1998; Comeau et al. 2000; Simard et al. 2001; Heineman et al. 2005; Ehrentaut and Branter 1990, Comeau et al. 1999). Depending on the severity of the brush hazard, two or three manual treatments may be required as an alternative to a single glyphosate treatment, making it a costly alternative.

No single vegetation control method suits all sites. Logistical, environmental and safety concerns also affect the choice of vegetation management. Forest licensees document when and how herbicides and other vegetation control methods are used in their Pest Management Plans.

Depending on the developmental stage of a plantation and its brush complex, glyphosate can be used to: clear a planting site of pre-established brush, to ensure plantation survival, or to meet free-growing requirements that ensure long-term productivity.

2.3.1 Site Preparation

Glyphosate is sometimes used to prepare a site for planting where highly competitive vegetation complexes have become established prior to planting. It can be difficult to spot crop seedlings in the brush and manual treatments can damage too many seedlings so it can be preferable to manage vegetation before planting. Failed plantations from forest pests or aggressive brush may require a herbicide site preparation treatment to re- establish a new plantation. The average annual area site prepared with glyphosate over the last 10 years is 152 ha/year, less than 2% of the area sprayed, and is mostly ground-based application.

2.3.2 Plantation survival

Plantations on sites with aggressive competing vegetation complexes can fail within a year without effective vegetation management. In these cases, interventions are often needed to avoid excessive seedling mortality and plantation failure (Comeau and Harper, 2009; Biring et al 2003; Comeau et al, 1999). Glyphosate application on these sites can reduce and slow down the growth of competitive species in order for the conifer crop to become established.

2.3.3 Crop tree productivity

Vegetation management may be required to release established crop trees that are over-topped by competing vegetation and at risk of failing to comply with free growing standards. A single application of glyphosate during the first few years after planting has been shown to effectively improve conifer growth 9 to 20 years later in a wide range of plant communities in various ecosystems in British Columbia (Harper et al. 1997a, b; Whitehead and Harper 1998; Biring et al.1999, 2000, 2001; Biring and Hays-Byl 2000; Simard et al.2001; Harper et al.2005; Boateng et al.2006; Macadam and Kabzems 2006). There is however substantial variation in the magnitude of these growth gains, and in certain cases the effects have been proven to be short-term (Comeau et al, 1999; Heineman et al, 2005; Comeau and Harper, 2009).

2.4 Area Treated

Provincial statistics from BC Ministry of Forests Lands, Natural Resource Operations and Rural Development's (FLNRORD) database, RESULTS show that roughly 11,000 ha of crown land were treated with glyphosate for silviculture in 2018[8] with 86% sprayed aerially and 14% sprayed using ground-based methods (Figure 1). This has declined from an average of 13,802 ha for the last five years and higher historical levels. The area sprayed in 2018 was 0.044% of the 25 M ha available for harvesting in BC and 0.44% of the tenured area on crown land that has an outstanding reforestation obligation.

A survey of pesticide use in 2017 (MOE unpublished draft) indicated that 13,800 ha were sprayed with glyphosate. Differences between the MOE and RESULTS spray areas could relate to different reporting methods and periods.

The proportion of area harvested area that has had any kind of vegetation control treatment has decreased from 18% to 14% over the last 10 years. Half the brushed area involved glyphosate over that

[8] This includes aerial and ground-based brushing and site preparation treatments excluding 'basal spray' and 'stem bark spray' silviculture methods which do not apply to glyphosate. It may include some triclopyr application that was reported as Backpack treatment method. Private land is not included.

time (Figure 2). Glyphosate use declined as salvage of Mountain Pine Beetle (MPB) mortality increased. As MPB salvage winds down, interior licensees are moving to wetter sites with greater brush hazards.

The main non-chemical methods used are brush saws, manual cutting and power saws (Figure 3). other methods including girdling, sheep grazing and stem bending with hockey sticks are used on a smaller scale.

The ground-based chemical treatments include backpack, notch or frill, spot cone, spot gun, stem injection, stump treatment, vehicle mounted sprayer and wiping. In recent years backpack spraying is by far the most common ground-based treatment while helicopters are the only aerial method used.

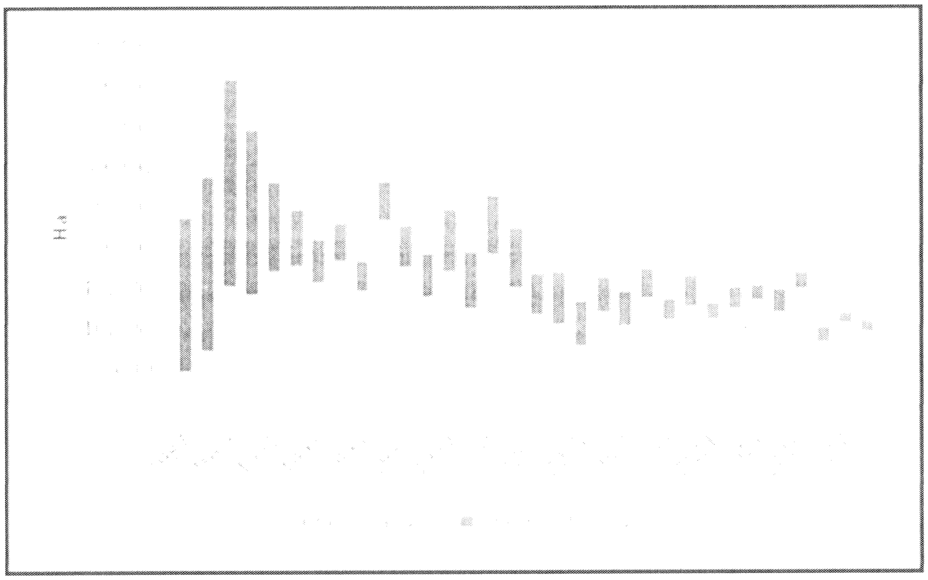

Figure 1. Area sprayed with glyphosate for silviculture in BC.

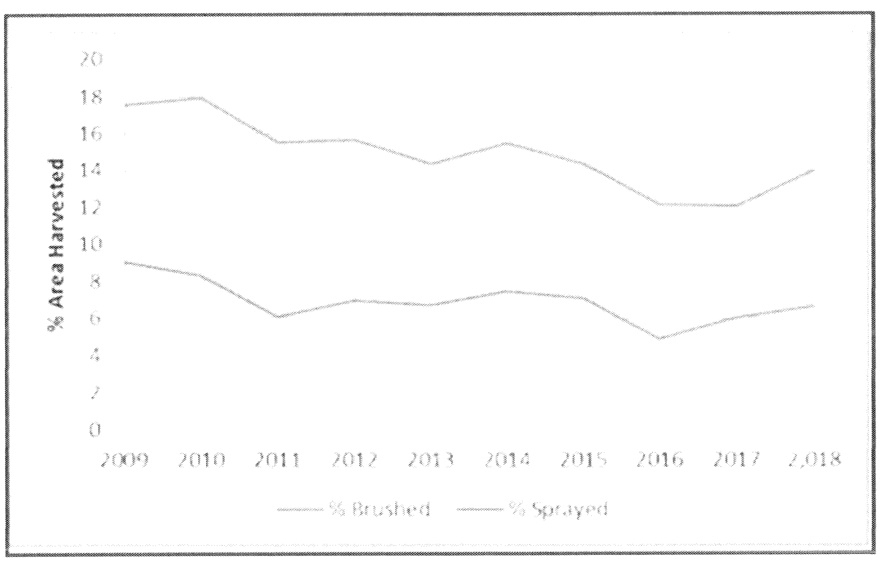

Figure 2. The percentage of harvested area that is brushed, and sprayed with glyphosate.

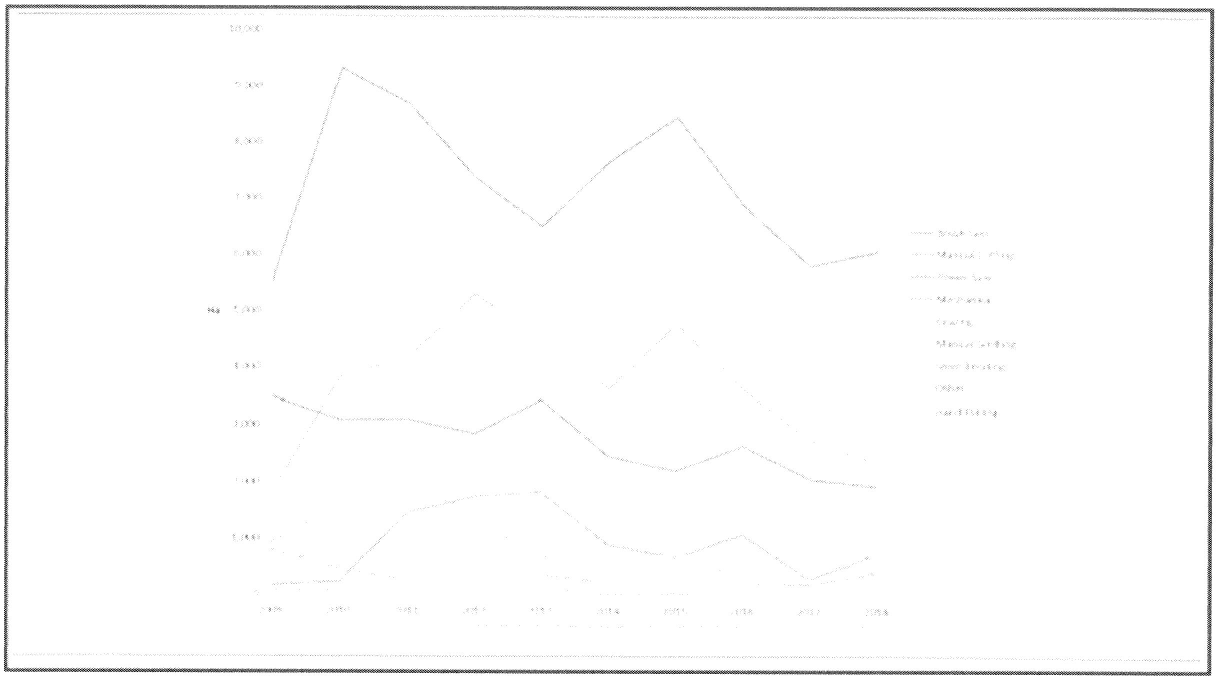

Figure 3. Area brushed with non-chemical methods.

The Omineca Natural Resource Region and the Northeast Region had the most glyphosate sprayed in 2018 with 73% and 11% respectively, of the total area sprayed (Table 1). The Prince George Timber Supply Area (TSA) comprised 68% of the area sprayed with glyphosate in 2018. Aerial applications made up 96% of the spray programs in those Regions. Small aerial programs also occurred in Thompson-Okanagan and South Coast Regions. Small ground-based programs occur in all regions with the largest program in the South Coast Region. The proportions of area harvested that were sprayed with glyphosate range from 11-15% for the South Coast, Northeast and Omineca regions, while the remaining regions in the province were less than 3% of the harvested area (Table 1).

Table 1. Area sprayed with glyphosate by Natural Resource Region (ha) in 2018.

Natural Resource Region	Chemical Air	Chemical Ground	Chemical Total	Harvested Area	Harvested %
		Ha			
Omineca	7,673	301	7,974	52,795	15.1%
Northeast	1,179	60	1,239	11,574	10.7%
Thompson-Okanagan	565	18	583	25,635	2.3%
South Coast	35	520	555	4,060	13.7%
Kootenay Boundary		234	234	14,333	1.6%
West Coast		175	175	10,620	1.6%
Skeena		169	169	16,346	1.0%
Cariboo		39	39	28,418	0.1%
Grand Total	**9,451**	**1,516**	**10,967**	**163,781**	**6.7%**

The biogeoclimatic (BGC) zones (Meidinger and Pojar 1991) that were sprayed the most are the Sub-Boreal Spruce (76%) and Boreal White and Black Spruce (9%) zones (Table 2). Four subzones of the SBS account for 68% of the sprayed area (Table 3). The drier SBS subzones-dry warm (dw) and moist cool (mk) are dominated by aspen; and the wetter subzones- wet cool (wk) and very wet cool (vk) are dominated by herbaceous vegetation. Aerial methods are used on 97% of those subzones. BCTS in Prince George indicated their aerial spray program last year targeted 349 ha for aspen and 311 has for herbaceous and non-deciduous.

While there are widely diverse vegetation complexes throughout BC with varying proportions of woody and herbaceous vegetation, herbaceous vegetation dominate on richer, wetter sites. Target species are indicated on brushing prescriptions developed from operational surveys (Appendix 2) but it is beyond the scope of this report to analyze the distribution of target species which are sprayed (Note inquiries to MOE and licensees are outstanding, but it seems challenging to get meaningful info). Often vegetation complexes are reported with combinations of species of grasses, herbaceous, woody shrubs and deciduous species.

Table 2. Area sprayed with glyphosate by BGC zone (ha).

BCG Zone	Air	Ground	Total
SBS	7,865	416	8,281
BWBS	941	60	1,002
CWH	27	662	688
ESSF	414	135	549
ICH	195	192	387
IDF		52	52
MH	8		8
Grand Total	**9,451**	**1,516**	**10,967**

Table 3. Area sprayed with glyphosate by BGC subzone (ha)

BGC Subzone	Area Sprayed	
SBS mk	2,907	27%
SBS wk	1,895	17%
SBS vk	1,462	13%
SBS dw	1,227	11%
BWBS mw	593	5%
CWH dm	521	5%
SBS mm	307	3%
BWBS wk	235	2%
ESSF wk	232	2%
SBS dk	224	2%
SBS mc	180	2%
BWBS mk	175	2%
ESSF mv	145	1%
ESSF wc	139	1%
ICH mw	109	1%
ICH vk	105	1%
Other	513	5%
Grand Total	**10,967**	

Most of the sprayed blocks have only a targeted portion sprayed at a time. Treated areas are usually dispersed over the landscape, interspersed with untreated areas. About a quarter of the sprayed cutovers in BC in 2018 had more than 90% of the net area reforested (NAR) sprayed (Table 4). The Thompson-Okanagan region had the highest proportion of NAR sprayed with 38% of sprayed blocks having more than 90% of the NAR sprayed. The Coast and Cariboo regions had comparatively high proportions of blocks with less than 10% of the NAR sprayed. With repeated treatments, the treated proportion of the NAR may increase.

Glyphosate is usually applied once or twice in a rotation. This is a contrast from agriculture and other common land uses where areas are sprayed repeatedly. Since 1998, 47% of ground-based blocks were treated once and 63% of aerial blocks were treated once. The percentage of blocks treated more than twice was 32% for ground-based and 11% for aerial in BC. The Coast regions had a higher proportion of retreatments (Table 5).

Table 4. Percentage class distribution of NAR area sprayed one time, by region.

Region	Percent Classes of NAR Sprayed									
	10	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Cariboo	19	14	12	9	10	9	7	5	5	10
Kootenay-Boundary	10	8	9	8	8	7	8	5	9	29
Northeast	5	5	6	5	7	8	9	10	14	31
Omineca	6	9	10	9	10	9	8	8	8	23
Skeena	9	9	8	7	7	8	7	8	11	26
South Coast	12	10	8	7	8	7	7	7	7	27
Thompson-Okanagan	8	10	6	6	5	5	5	8	8	38
West Coast	23	14	11	10	7	5	5	4	5	16
BC	**11**	**10**	**9**	**8**	**8**	**8**	**7**	**7**	**8**	**24**

Table 5. The percent distribution of number of treatments of ground-based and aerial treatments by Region since 1998.

	Ground			Aerial		
	Number of Treatments					
	1	2	>2	1	2	>2
Cariboo	74	20	6	83	16	1
Kootenay	44	42	14	100	0	0
Northeast	64	25	12	53	30	17
Omineca	89	10	1	68	24	8
Skeena	79	11	10	70	15	15
South Coast	41	29	30	79	21	0
Thompson	75	17	8	45	33	22
West Coast	24	19	58	63	25	11
BC	47	21	32	65	25	11

2.5 Treatment costs

Treatment costs will vary considerably depending on location, access, treatment intensity, availability of crews and equipment, logistics, etc. Early treatments are cheaper when target stems are smaller, but regrowth could require an additional treatment. There are also associated costs with layout and monitoring.

Licensees reported that manual treatments ($700-1200/ha) are twice the cost of glyphosate treatments ($300-500/ha) and require at least two treatments. The cost of achieving free growing is roughly $1,100-1,900/ha more without glyphosate. Applying an average cost of $1,400/ha (Table 6) to the 11,000 ha area that was sprayed in 2018, the cost of constraining glyphosate for silviculture is estimated at $15.4 M.

Table 6. Cost comparison to achieve free growing, Prince George BCTS example. Brushing treatments include layout and monitoring.

	With glyphosate	Without glyphosate

Site prep ($/ha)	$1,160	$1,160
Plant regular stock ($/ha)	$ 624	
Plant large stock ($/ha)		$ 900
Glyphosate spray ($/ha)	$ 354	
Manual brush ($/ha)		$ 730
Manual brush ($/ha)		$ 730
Surveys ($/ha)	$ 75	$ 90
Cost to free to grow ($/ha)	$2,213	$3,610
Volume harvested (m^3/ha)	300	300
Cost to free grow ($/$m^3$)	$ 7.38	$12.03

The Prince George example (Table 6) shows additional silviculture costs of $4.66/$m^3$ to achieve free growing without glyphosate. Costs could be higher where additional manual entries are required and treatment costs are higher. In Quebec, plantation establishment and tending costs frequently exceed $5,000/ha due to planting large stock and as many as three manual brushing treatments (Labbé et al. 2014). Dampier et al (2006) reported that cost per cubic metre of wood tripled when conifer release was performed by motor-manual methods rather than aerial application of herbicide.

In a market where log costs are high, timber supply is declining and marginal economic decisions are made, the impacts of increased wood costs could be significant. Cost increases greater than $4/$m^3$ may reduce harvest levels as some stands would become uneconomic. Some of this cost could be recovered from appraisal offset but there is a six month delay.

2.6 Stocking Standards

Administrative mechanisms that allow greater flexibility in stocking standards could facilitate reduced brushing and glyphosate use and accommodate other values. Decisions on the use of glyphosate are vegetation management as well as forest management decisions.

There are ongoing efforts to further develop standards to facilitate deciduous management. Examples include fire stocking standards in the Wildland Urban Interface, including the establishment and management of deciduous species to reduce fire behaviour in proximity to communities and

[redacted]

infrastructure[9]. A Hardwood Management Strategy was developed in 2008 to facilitate management of red alder, bigleaf maple and birch in the Coast Region[10]

Alternative stocking standards for a FSP must be supported with science and justified with timber supply considerations and other tests[11] In some parts of the province the focus on coniferous species remains a hurdle to alternative standards as the science for deciduous management is not well understood. How much deciduous stocking is justified and what is the effect on conifer productivity for key BGC subzones? Further supporting research and guidance such as Newsome and Heineman's (2016) mixedwood stocking standards for the Cariboo Region would assist managers in developing stocking standards that can incorporate other non-conifer values.

Stocking standards have the unintended consequence that brushing is sometimes carried out to meet administrative requirements with little impact on stand development. This is the case in plantations where the crop trees may not be significantly affected by the competing vegetation, or where hardwoods recover after treatment and overtop the crop trees again after a stand has been declared free growing.

An approach to reduce costs and burden might be to identify potential brush areas at the timber development stage and exclude them from site plans, or remove them from the net area to be reforested. Another approach used in the Fort St. John pilot project allows for 2 ha or 20% of non-satisfactorily restocked (NSR) area over the landscape[12]. The concept allows areas of poor performance which are compensated by areas of superior performance. This allows greater flexibility and efficiency to use resources where higher yields can be achieved and avoids expensive treatments of poor value.

Baleshta et al (2015) suggested that free-to-grow standards be adjusted to focus more on the health, diversity, and stability of forests at larger scales rather than fast individual conifer growth for saw log production.

Determinations on allowable deciduous components could also be made at the Timber Supply Review level as the Chief Forester provides guidance on ecological suitability which affects stocking standards.

In the 2017 AAC Rationale for Prince George TSA[13] ministry staff considered deciduous harvest performance over the past decade, the current economic environment as well as the demand for deciduous wood products. This operability assessment was used to determine the contribution of deciduous-leading stands in the AAC which was adjusted to 62,000 m^3 from a previous level of 160,000 m^3. As economic opportunities such as oriented strand board and bioenergy facilities become available a greater deciduous component could be included in the Timber Harvest Land Base (THLB). The uneconomic deciduous stands excluded from the Prince George THLB contribute significantly to stand and landscape biodiversity objectives. Deciduous leading stands provide valuable wildlife habitat such as winter cover for moose, wildlife movement corridors, and specialized habitat for elk, fisher, small mammals and songbirds.

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9 https://www.for.gov.bc.ca/hfp/silviculture/Fire%20Management%20Stocking%20Standards%20Guidance%20%20Document%20March%202016.pdf

10 https://www.for.gov.bc.ca/rco/stewardship/CRIT/docs/Hardwood%20Management%20in%20the%20Coast%20Forest%20Region%20(final%20July11V2).pdf

11 https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/stocking-standards

12 http://www.fsjpilotproject.com/documents/SFMPappend2016/Appendix_6_Reforestation_Strategy_Stocking_Standards_and_Crop_Tree_Requirements.pdf

13 https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/tsr-annual-allowable-cut/prince_george_tsa_rationale_2017.pdf

2.7 Impacts on Timber Supply

Any constraint on the use of herbicides for vegetation control should consider the potential impacts on timber supply. This is considered when stocking standards are proposed but cost and implementation are also considerations. In many cases, alternative vegetation management treatments can successfully be applied and forest management objectives can be met. In other cases, increased silviculture costs may affect the economic viability of select stands or result in a net down of the timber harvest landbase. Some of the most productive growing sites are the most challenging to reforest due to brush competition.

Intensive silviculture strategies applied as an alternative to glyphosate treatments may also be less effective resulting in reduced stocking and stand productivity. in Canada, decisions to not use chemical herbicides have been taken in Quebec and Nova Scotia. In Quebec, a provincial ban of glyphosate use on Crown land took effect in 2001 after a series of public consultations. Forest regeneration would focus on early planting of tall stock and intensive manual brushing. However, mechanical release alone did not promote optimal crop-tree growth due to rapid resprouting or suckering of competitors and competition from herbaceous species. There were challenges managing plantations where the objective is to maximize wood production (Thiffault and Roy, 2011). Since then, the Chief Forester's Office has reported challenges in reaching proper stocking. In some areas, over half of plantations did not reach the required stocking due to severe competition (Bureau du forestier en chef, 2015).

An audit of plantations in Nova Scotia yielded similar results. Results showed 87% of conifer plantations were considered failures, and a further 10% did not meet free growing standards 6-8 years post-harvest (Nicholson, 2007).

Currently, failure to meet free growing requirements occasionally occurs in BC despite diligent efforts. Plantations can fail and there are instances where overcoming aggressive vegetation can only be met to the extent that is practicable with a subsequent request for relief from obligations under FPPR sec 97.1. Increasing the challenge to meet free growing without glyphosate on a broad scale may increase the risk for reduced plantation performance.

3 Impact of glyphosate use on non-timber values

Forest professionals manage the forest resource for all values. Most of the forestry related impacts on non-timber values result from forest management decisions made at the development stage and occur from harvesting methods and road building. The following section considers glyphosate use in terms of non-timber values.

3.1 Soil and water quality

Glyphosate is easily immobilized in the ecosystem due to its ability to easily bind with soil particles and organic materials. The main pathway for glyphosate dissipation in soil is microbial degradation, as many species of soil microorganisms can use glyphosate as their soil carbon source (Durkin, 2003). This is particularly the case in the LFH layer and upper soil horizons, where microbial activity is highest:

studies have found that the time for 50% dissipation (DT50) in litter and soil is 8 to 19 days, and 5 to 40 days respectively (Newton et al 1984; Newton et al, 1994; Thompson et al, 2000)

The mandated use of no-treatment pesticide-free zones around water features, the strong sorption to upper soil layers and the rapid uptake by plants minimize the risk of glyphosate entering aquatic ecosystems. The main ways that glyphosate could end up in aquatic ecosystems are by drift or by soil particle mobilization after a storm event in the hours following glyphosate application (Rolando 2017). These risks are minimized in field operations by the use of electronic guidance systems, low drift nozzles, and meteorological monitoring of wind speed, temperature and humidity (Thompson et al., 2012). In the field, studies have consistently shown low probability and magnitude of inputs into aquatic ecosystems when buffers and typical mitigation actions are undertaken (Thompson et al. 2004, Feng and Thompson 1990; Gluns et al. 1989; Adams et al. 2007). However, drift onto non-target vegetation both within and outside targeted blocks still does occur (Wood 2019).

Once in the water however, studies have shown DT50 for glyphosate of less than 5 days. Studies in streams and wetlands have shown no detectable glyphosate residues in the water after 15 days (Rolando 2017). Glyphosate does persist longer in oligotrophic water bodies or those that are cold, deep and somewhat biologically inactive. Residues have been detected in benthic sediments of these systems for up to 18 months after application. [51,52,56J6]. The primary mechanisms behind the rapid breakdown o 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.[51,52,56,73,76].

3.2 Biodiversity

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

3.2.1 Non-target plant communities

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

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

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

While glyphosate tends to result in a larger initial reduction of a wider range of species, it's important to note that other brushing alternatives such as manual brushing have similar effects on plant communities. 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 as compared to two mechanical vegetation control treatments, but that woody, herb and grass layers recovered to pre-treatment levels within five years.

3.2.2 Broadleaf tree species

Mixedwood forests provide various ecological, social, and non-timber values; have significant value in shaping forest ecology, stand structure, and function; and exert a strong influence on forest diversity and resilience (Harper 2014). Public concerns that the use of herbicide (and vegetation management, more broadly) in B.C. is eliminating broadleaves from the landscape have been increasing in recent years, particularly after the catastrophic wildfire seasons of 2017 and 2018. These concerns are beyond the scope of glyphosate use however, as the acceptable amount of broadleaf components in newly established stands is regulated via stocking standards and can be enforced by other vegetation management alternatives.

3.2.2.1 Aspen regeneration post-harvest and persistence after herbicide

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

On these sites, mixedwoods often result even after conventional vegetation management efforts (including glyphosate), as a percentage of broadleaves in a treated stratum may survive, resprout or produce suckers after treatment (Kabzem and Harper, 2015; Bell and Newmaster, 2002; Perala, 1985, Navratil et al. 1991; Pitt et al. 2004a; 2004b; Pitt and Bell 2005). Medium- and long-term studies in boreal sites that assessed the effect of a one-time glyphosate application on stand composition have found 15-21% deciduous stand components 5-30 years after treatment (Kabzem and Harper, 2015; Pitt et al. 2004a; 2004b; Pitt and Bell 2005).

While those studies focused on deciduous composition in herbicide-treated areas, it's important to note that glyphosate is not generally applied to entire harvest units. The total elimination of competitive vegetation is not a silvicultural objective of conifer-release programs (Smith et al 1997, Bell and Newmaster 2002). In B.C., vegetation management treatments, including glyphosate application, are carried out only in the portions of a harvest unit where they are deemed necessary for conifer survival or to meet free-growing stocking standards in a given standard unit as per Sec 46.11 of the FPPR.

3.2.2.2 RESULTS analyses

A 2008 Forest and Range Evaluation Program (FREP) review of species diversity pre- and post-harvest in B.C. found that the amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods (BCMFLNROR 2008). Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing, a 3,000% increase.

An up-to-date RESULTS query of stand composition for all stands declared free growing following herbicide treatment (aerial and ground-based) was prepared for this report by FLNRORD. The inventory labels from free growing surveys were analyzed for openings that were surveyed 2-25 years after spraying and that have been sprayed >5 years after harvest. More than one herbicide treatment may have occurred, and the analysis used the number of years since the last treatment for the survey polygon.

Province-wide, the average number of deciduous stems/ha in a survey polygon after ground-based and aerial spraying was 449 and 504 stems/ha, respectively (Table 7, Figure 4). This translates into 15% and 16% broadleaf components (by stem density).

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

In the Northeast and Omineca Regions, which have the highest proportions of sprayed areas, the average number of deciduous stems/ha at free growing following aerial herbicide treatments were 864 and 445 st/ha, or 27% and 15% of the total stand species composition (Table 7). The averages shown in Table 7 do not show the variation in sample sizes and stocking that can occur from year to year or among openings.

Table 7. Deciduous stocking based on the inventory label at free growing following aerial and ground-based herbicide treatment by region. The sample size is described by the number of years (2-25) following treatment and the average number of ha surveyed by year. Stocking is shown as stems/ha of deciduous and % of total stems.

Region	Sample	Aerial			Ground		
	Years	Avg Ha/Yr	% Stems	St/ha	Avg Ha/Yr	% Stems	St/ha
BC	25	13,219	16.4%	504	9,071	14.6%	449
Omineca	25	7,186	14.7%	445	2,007	21.2%	699
Northeast	25	3,399	26.5%	864	938	27.6%	828
Cariboo	13	2,990	9.6%	436	2,914	12.6%	583
South Coast	16	765	4.8%	94	1,558	7.2%	120
Kootenay	16	271	4.1%	130	654	5.2%	185
Skeena	13	340	8.9%	237	1,485	7.7%	230
Thompson	15				1,330	8.9%	355
West Coast	15				9,071	14.6%	449

Similarly, the SBS zone which is by far the most sprayed BEC zone (Table 2) has an average of 455 and 577 stems/ha of deciduous at free growing for aerially and ground-based treated openings, respectively. There is a slight downward trend in deciduous stocking over time, likely due to shading out of aspen. Trends and changes in deciduous stocking over time are generally weak and variable for other regions and zones.

The results of the analysis suggest that aspen stocking does recover after spraying and contribute to biodiversity.

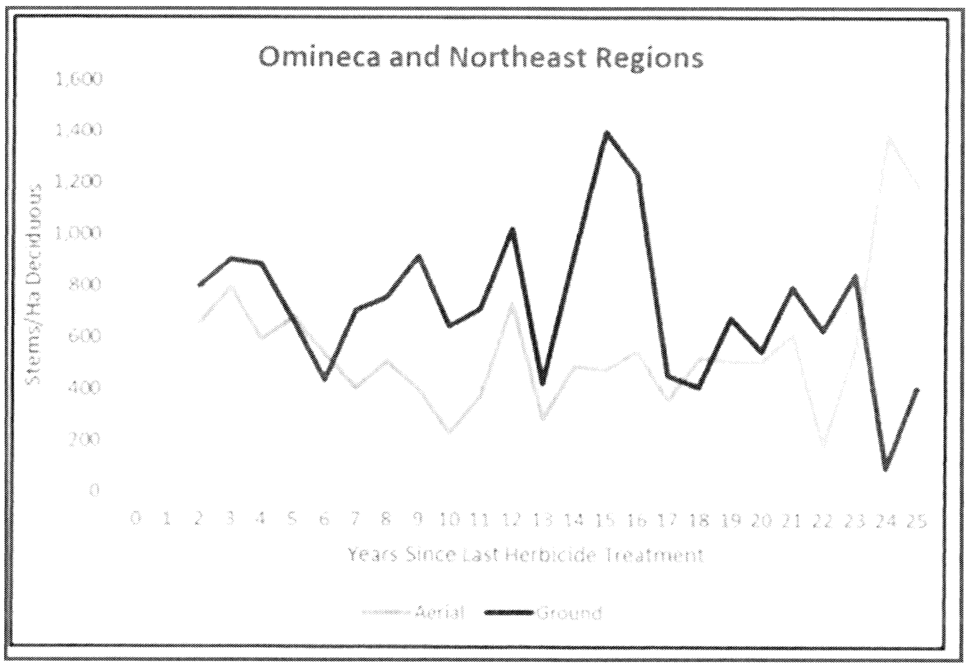

Figure 5. Average stems/ha deciduous at free growing in openings with one more herbicide treatments in the Omineca and Northeast regions.

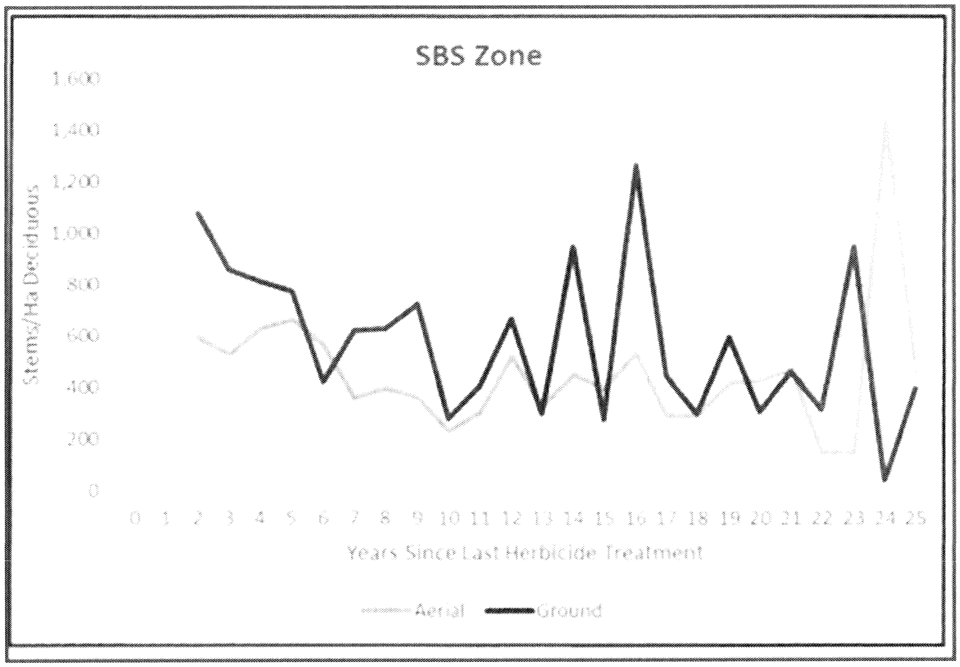

Figure 6. Average stems/ha deciduous at free growing in openings with one more herbicide treatments in the Sub Boreal Spruce biogeoclimatic zone.

3.2.2 Aquatic ecosystems

Amphibian populations are declining around the world (Houlahan et at 2000), and chemical contaminants released to aquatic environments have been listed as the second most important threat to amphibians after habitat loss (Vie et al ., 2009, Edge et at 2011). Laboratory and mesocosm studies have shown direct effects of chronic glyphosate exposures on fish, amphibians, invertebrates and other components of the ecosystem ((e.g. Folmar et al. 1979; Wan et al. 1989; Howe et al. 2004; Edglnton et al. 2004; Edge et al. 2014a, Lanctot et al. 2014, Navarro-Martin et al. 2014). Studies have not been able to replicate these toxicity effects in the field under typical application rates and conditions, however.

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

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

Studies did find temporary effects on aquatic ecosystems associated with changes to the vegetation after glyphosate application. Glyphosate application caused a decrease in total macrophyte cover and species richness, an increase species evenness, and a reduction in community similarity when compared to unexposed wetland sides (Baker et al. 2016). One year after herbicide applications the wetland vegetation began to recover. Another study found that 10% of the benthic macro invertebrate taxa were lost after herbicide application but recovered in one year (Baker et al. 2014).

While these studies investigated the effects of glyphosate application directly over aquatic ecosystems, integrated pest management regulations in B.C. mandate the use of no-treatment pesticide-free zones around water features, dry streams and classified wetlands (I PM regs, sec. 73 (1)), further reducing the risk of negative effects on aquatic ecosystems. Various Canadian studies on surface water glyphosate residue have found no detectable glyphosate or AMPA, the breakdown product of glyphosate, concentrations (ie. <5,000 j.lg a.i./L1) post-treatment when using buffers of l00m for aerial and 10m to 60m for ground applications. (Wan, 1986; Eremko, 1986; Gluns, 1989; Adams et al, 2007). Canadian Water Quality Guidelines (CWQG) for the protection of aquatic wildlife stipulate maximum short term and long term glyphosate exposures of 27,000 llg a.i./L and 800 llg a.i./L respectively. These values are based on median lethal dose (LCso) data for 19 aquatic species (CCME, 2012).

3.2.3 Wildlife

Several studies on the direct acute or chronic toxicity effects of glyphosate on small mammals, large mammals and birds have found risk quotients below the level of concern with typical field application rates (Durkin et al., 2003; Giesy et al. 2000; PMRA, 2015). Effects on terrestrial wildlife communities, like in aquatic ecosystems, are therefore linked to the changes in vegetation cover. As such, species responses are highly variable and reflect individual habitat preferences. Studies on wildlife response to habitat alteration from glyphosate application have shown no effect, short-term negative effects and positive effects on different wildlife species (Guynn et al 2004). All in all, studies suggest that species richness and diversity of small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes are transient (sullivan and Sullivan 2003)

3.2.3.1 Moose [incomplete]

It is suspected that declining moose populations in BC are due to food shortages and that glyphosate application is contributing to a shortage of forage.

Stakeholders have raised concerns that reforestation efforts have focused on conifer establishment at densities that shade out deciduous browse species. In some cases, glyphosate control of competing species reduces biodiversity of the site. The 2016 *Strategy to Help Restore Moose Populations in British Columbia* (Gorley 2016) indicates that balanced objectives for timber and moose should occur at the landscape and cutblock levels and makes the following recommendations.

- Treat natural disturbances such as wildfire and beetle-kill, as well as salvage logging, as an opportunity to recruit habitat, and manage accordingly.
- Review and update applicable silviculture strategies to enable habitat recruitment where needed- place a high priority on population restoration project areas.

- Where requirements for achievement of "free to grow" are incompatible with habitat recruitment needed to meet moose objectives, amend them.
- Provide guidance to professionals responsible for planning timber harvesting and silviculture regarding their responsibility to accommodate habitat objectives.

Jennifer to provide more wildlife input.

Andrew Weaver - we have a program where we've initiated a two-year study to look at the impacts of herbicide spraying on feed and moose forage and nutritional quality of moose forage21

Add stuff on Caribou-- Note for example that spraying next to caribou habitat good (reduces no. of moose, and wolves}-from mtg

3.3 Climate Change

Future climate change could have important implications for trees that are becoming established today, and which will form the next generation of trees. It is important that climate change considerations be incorporated into current reforestation practices, policies, and approaches. Further research is needed to identify the role of silviculture treatments in mitigating stand vulnerability to fire, insects and drought. Maintaining healthy, resilient and productive stands can ensure that trees are robust in the face of climate change. This could be facilitated by maintaining a diversity of age classes and species[14,15]

Effective forest management in a changing climate requires understanding what climate changes are occurring now and in the future both regionally and locally, how this will affect forest growth and productivity, and strategies for addressing climate change impacts. For example, some strategies include enhancing tree species diversity, matching planting stock to potential future climatic environments, and addressing the anticipated impacts of fire, insects and disease. These factors speak to the overarching need for forested landscapes that are resilient to management actions and a range of potential future climates[16]

BCMFLRNRO's Climate Action Roadmap (2013) identifies adaption as one of the four pillars of climate action[17]. One of the Adaption Strategies to reduce risks to forest ecosystems includes promoting resilience to change by:

- promoting stand-scale species diversity (e.g. retain broadleaves and plant more species)

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[14] https://www.ccfm.org/pdf/TreeSpecies_web_e.pdf

[15] https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nrs-climate-change/adaptation/management_options_may9_2012.pdf

[16] https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nrs-climate-change/mitigation/climatemitigationpotentialofbritishcolumbianforests.pdf

[17] https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nrs-climate-change/flnr-climateactionroadmap.pdf

- promoting landscape-scale ecosystem diversity (e.g., age-classes, leading tree species, structure)[18]

Vegetation management including glyphosate application can impact stand-scale and landscape-scale species diversity. However vegetation management is one part of forest management and there may be greater impacts to diversity from harvesting and reforestation methods.

Dymond et al (2014) found that simulations to harvest the most dominant tree species, plant more diverse species and increase natural regeneration resulted in greater ecological resilience (higher diversity and growing stocks), higher harvest rates, and higher, more consistent net revenue over time than the business-as-usual strategy or the strategy that only employed a diversity of planting.

3.3.1 Carbon

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 stand yield, and carbon sequestration. Harper and Roach (2014) indicated that the Mixedwood Growth Model (Bokalo et al 2013) showed reduced spruce volume at rotation when broadleaves are included in stands. The reduced conifer volume was compensated by broadleaf volume which results in similar or higher total volume for conifer plus broad leaved stands compared to pure stands. Mixedwood stands 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). Retaining between 1,000 and 10,000 stems/ha might be expected to increase total production by about 20% relative to a pure spruce stand, but this will be at the expense of spruce volume (Kabzems et al 2007). However, Roach (2013) indicates that while growth and yield implications of managing for mixed versus pure stands are documented more frequently than influences of other values, information is still too limited to conclusively compare the productivity of mixed versus pure stands (Roach 2013).

Gough et al (2019) found that structurally complex forests are better at carbon sequestration. Gough suggests that multiple layers of leaves may optimize how efficiently light is used to power carbon sequestration in wood. Forests that are structurally variable and contain multiple layers of leaves outperform structurally simple forests with a single concentrated band of vegetation.

Laganiere et al (2017) found that aspen stored less carbon in the forest floor but similar amounts in the mineral soil relative to conifers. Soil organic carbon stock under aspen is more stable, rendering it more protected against environmental changes and soil disturbances. Their analysis highlighted that an increase in the abundance of trembling aspen in North American forests may increase the resistance and resilience of soil carbon stocks against global changes.

[18] https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nrs-climate-change/applied-science/1_va_intro20final20sept11.pdf

3.4 Wildfire

Deciduous stands often act as natural fire breaks. Fires in deciduous stand are usually slower moving surface fires which are easier to suppress than crown fires (Alexander and Lanoville, 2004). In summer months deciduous stands moderate microclimates, inhibit wind movement, help maintain lower air temperature and humidity and maintain soil moisture. Surface fuels, litter and herbaceous layers retain moisture longer into the fire season. Because of the usual absence of ladder fuels in deciduous stands, fire does not get carried into the crowns of these trees. The physical properties of aspen also resist intense fire behaviour (Alberta 2012). Aspen's effects on fire behaviour have made it a popular choice for fuel treatments in the wildland urban interface throughout North America (Gray 2018, Shepperd et al 2006).

Where forest stand conditions should be maintained to achieve fire management objectives, fire management stocking standards should be applied. Forest stands are not static and fire management stocking standards should achieve fire management objectives as the stand changes over time. The aim should be to reduce the likelihood of a crown fire or a fast-moving ground fire and balance a number of objectives (e.g. timber production, ecosystem restoration, broadleaf management, etc.) in an ecologically, socially acceptable and economically compatible framework[24]. Deciduous species are relatively resistant to fire (Table 5) and can be incorporated into fire management stocking standards to reduce fire behaviour in proximity to communities and infrastructure (BCMFLNRORD 2016). It is reasonable to believe that a potential expansion of deciduous species in boreal forests, either occurring naturally or through landscape management, could offset some of the impacts of climate change on the occurrence of boreal wildfires (Terrier et al 2013).

Table 5. Fire resistance of broadleaved species (BCMFLNRORD 2019).

Fire Resistance/Resilience	**Broadleaved Species**
High	balsam poplar, black cottonwood
High- Moderate	Gary oak, bigleaf maple
Moderate	trembling aspen, red alder, paper birch
Low	arbutus

Generally, deciduous fuel types are predicted to have lower fire behaviour potential than coniferous stands under similar fire weather indices, especially during leaf-on conditions. During spring months, the grass has the potential to dry out rapidly in the absence of canopy cover, creating a higher surface fire potential until green-up and leaf-on occurs. The Canadian Forest Fire Behaviour Prediction (FBP) system is used to predict the fire behaviour in several different common fuel types in Canada. This prediction is made using the Initial Spread Index (ISI) which is derived by considering the Fine Fuel Moisture Content (FFMC) and the predicted wind speed, and the Build-up Index (BUI) which is derived from the Drought Code (DC) and the Duff Moisture Content (DMC). The FBP system indicates that coniferous fuel types are predicted to exhibit more aggressive fire behaviour than leafless deciduous or the leaf-on mixed wood fuel types. This system predicts that high intensity fire occurs at much lower ISI and BUI values in coniferous fuel types than in deciduous fuel types. In addition, the FBP system predicts that crown fire will not occur in the deciduous fuel type (Taylor et al1996).

The effect on fire behaviour from deciduous vegetation treated with glyphosate is not well documented. It is expected that the fire hazard in treated dead stems following treatment either manually or chemically, would be very high. Dead aspen burns very hot (R.W. Gray pers comm). Further study would be required to determine the persistence of high hazard conditions.

Glyphosate treatment rarely eliminates all broad leaf stems as some recover or resprout and there are untreated adjacent areas. More information is needed on the recovery of broad leaf stocking following glyphosate application. If broad leaf stocking is limited due to stocking standards and free growing requirements, it is possible that fire spread rates and intensities could be affected in some ecological conditions.

Unpublished information indicates that mixed stands provide benefits, but clumping is better because it creates breaks in the canopy, which can slow fire spread in crowns (Misener 2009) (in Roach)

Across our boreal forests, poplar species including aspen have the lowest probability of burning. In a Canadian study, pine forests burned 840% more than deciduous forests (Cummings, 2001). In another study, researchers estimate broadleaf forests to remain next to inflammable even as drought conditions worsen, in stark contrast to coniferous forests (Girardin, 2013).

3.5 First Nations

There is a great deal of opposition to herbicides from many First Nations. Primary concerns are plants that are gathered for food or medicinal purposes which are killed directly by glyphosate or are considered contaminated. Residual chemicals in plants and wildlife could affect human health and impact the environment. As stewards of the land First Nations are concerned about the effects of chemicals on all aspects of the environment. Where there is doubt concerning the science about herbicides, there can be an inclination toward the precautionary principle.

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."[19]

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.

First Nations that have good planning relationships with forest companies can usually deal with issues in an appropriate way. Many First Nations are building planning relationships, which takes time and effort. In many cases these planning relationships are relatively new and glyphosate may not be a high priority. Glyphosate may be an issue to some groups such as the McLeod Lake Band, but it has not come up at the policy level very often (G. Merkel, pers.comm). It is preferable to take a proactive approach to problem solving rather than being reactive. Few groups are interested in site by site discussions but prefer collaboration and joint problem solving.

Education is important. Forest companies benefit from listening to First Nations and being educated on First Nation concerns. Once forest companies explain the rationale behind glyphosate use, why, where,

19 https://acuriouslookatpoliticsinbc.blogspot.com/2019/09/adam-olsen-skeetchestn-indian-band.html?fbclid=IwAR3kXSjKGMzGu6V5qs4Gxvu9l06PdbVbL5TtjdfWvallemumCz0TiAsRnaQ

how and when it is proposed, an understanding can often be reached. It is important to spend time to engage and discuss specific concerns. Good engagement can often resolve issues, but it may not be possible to satisfy everyone. The referral process within a PMP calls for meaningful consultation and accommodation. Licensees have indicated that there is often good engagement with First Nations and efforts are made to accommodate their concerns such as:

- Designated no spray areas
- Manual treatments
- Backpack instead of aerial application
- Spot spray around individual stems
- Increased buffers
- Leaving untreated patches
- Providing alternative gathering sites

3.6 Public Use

Opposition to the application of chemicals in the forest has been ongoing since the 1960s. Public pressure to reduce glyphosate use has increased since the Monsanto court cases and social media has heightened concerns over toxicity and ecological impacts. People are very concerned about the application of chemicals to the forest, the impacts to human health from being exposed to herbicides while hunting, fishing, berry picking, mushroom picking, firewood cutting, camping or hiking. People are concerned about chemicals in the environment and long term impacts.

PWRA (2015, 2017) has addressed many of these concerns. For example, 'products containing glyphosate are unlikely to affect your health when used according to label directions.' Dose levels used to assess risks are established to protect the most sensitive human population. This applies to people that may come in contact to glyphosate from food or water, or handling the product or by entering treated sites. The Food and Drug Act and Regulation (subsection B.15.002(1) indicates that Maximum Residue Limits (MRL) should not exceed 0.1 ppm.

Wood (2019) found unexpected high levels of glyphosate residue in plants a year following aerial application in the Peace River Region of BC. High levels of glyphosate residues and aminomethylphosphonic acid (AMPA) were found in herbaceous perennial root tissue as well as shoot and fruit material of select species. The average glyphosate level was 0.79 ppm and highest level detected was 4 ppm which is well above the limit of 0.1 ppm set by the Canadian Food Inspection Agency for any undesignated food. Average levels of glyphosate residue in blueberries and raspberries were about .14 ppm. The study indicated that perennial plants that were not killed by the glyphosate treatment can isolate glyphosate in roots during dormancy and translocate it to shoots and fruit in years following glyphosate treatment. Persistent levels of glyphosate may have implications for edible and medicinal use of native plants. Further research is required to understand the timelines that glyphosate can persist in plants. Persistence is related to climate and ecology. It may be possible to develop tools to assess the level of persistence.

Wood (2019) points out, “Some people feel that any level of glyphosate contamination is unacceptable, and therefore, it becomes an ethical choice to make sure that information is available about the possible presence of glyphosate in forest plant tissues.”

Signage requirements could be improved to provide better information on glyphosate persistence in plants.

3.7 Range in Variation of Species

Conservation of genetic diversity provides the capacity for native species to adapt to new environmental conditions (Chourmouzis et al 2009). Little information is available on how glyphosate use has impacted the range of species. Impacts on rare plants and wildlife are usually assessed during development of silviculture prescriptions. Brushing prescriptions are developed from post-harvest surveys and are part of the reforestation strategy of the silviculture prescription (Appendix 2). Sensitive values identified in the silviculture prescription should be addressed in brushing prescriptions as well.

Aspen has expanded following MPB?

Moose

Migratory birds

Executive Summary (incomplete, rough)

Regulatory framework

Health Canada Pest Management Regulatory Agency (PMRA) registers and regulates herbicide use in Canada. PMRA reapproved the use of glyphosate in Canada in 2017. In January 2019 Health Canada indicated that after a thorough scientific review, objections to the re-evaluation decision to register glyphosate in Canada could not be scientifically supported when considering the entire body of relevant data. " No pesticide regulatory authority in the world currently considers glyphosate to be a cancer risk to humans at the levels at which humans are currently exposed" (Health Canada 2019). This is supported by the European Food Safety Authority, the WHO and FAO Joint Committee, the American Environmental Protection Agency, the committee for Risk Assessment of European Chemicals Agency, and the Australian Pesticides and Veterinary Medicines Authority.

There are high standards for handling and applying glyphosate in BC as regulated under the Integrated Pest Management Act and Regulations.

Reforestation requirements to achieve free growing standards are outlined in the Forest and Range Practices Act (FRPA) and the Forest Planning and Practices Regulation. Stocking standards in Forest Stewardship Plans are approved by the District Manager. Mappable areas that do not meet stocking standards should not exceed 2 ha or 5% of the Standard Unit area.

Best Practices

Pest Management Plans (PMPs) document ment how integrated vegetation management will be implemented and indicate standards for consultation, notification, reporting, herbicide handling and application. Alternatives to using herbicides and protecting the environment are also indicated. Strategies and procedures for herbicide use have evolved in PMPs since 2004.

Why used

Glyphosate is a cost-effective and efficacious vegetation management tool used mainly to:

- prevent plantation mortality from aggressive vegetative competition
- meet free growing obligations that ensure crop tree productivity

Glyphosate is one of many vegetation management tools available to forester managers. It is very effective because it is easily translocated within the target plant, usually killing it, and reducing the brush hazard for multiple years after a single application.

Area treated

Roughly 11,000 ha of crown land were treated with glyphosate for silviculture in 2018[20] This has declined from an average of 13,802 ha for the last five years and higher historical levels. This sprayed

[20] This includes aerial and ground-based brushing and site preparation treatments excluding 'basal spray' and 'stem bark spray' silviculture methods which do not apply to glyphosate. It may include some triclopyr application that was reported as Backpack treatment method. Private land is not included.

area was 7% of the area harvested in 2018 on BC crown land, and less than 0.5% of the area that has outstanding reforestation obligations.

The proportion of area harvested that has received any kind of vegetation control has decreased from 18% to 14% over the last ten years. Half of the brushed area involved glyphosate over that time.

Most of the spraying occurs in the Omineca Natural Resource Region with 73% of the area sprayed in BC, followed by the Northeast Natural Resource Region with 11%. Most of the spraying occurs in the SBS BEC zone with 76% of the spray program followed by the BWBS zone with 9% and the other BEC zones comprising 15%.

Most of BC's spray program was applied aerially (86%) and only 14% was applied using ground-based methods.

Glyphosate is generally sprayed in a single site once over a rotation. Since 1998, 47% of ground-based blocks and 63% of aerial blocks were treated once.

Province-wide, 68% of blocks have <90% glyphosate treatment coverage. Treatment coverage made up less than half of the block area approximately half of the time.

Cost

Licensees have indicated that switching from glyphosate to alternative silviculture methods would add extra cost of $1,400/ha to achieve free growing. This cost applied over the area sprayed in 2018 would have a total cost of $15.4 M per year. Licensees have indicated that the added cost/m^3 to reforest without glyphosate would be $4.66/$m^3$.

Stocking standards

Administrative mechanisms that allow greater flexibility in stocking standards could facilitate reduced brushing and glyphosate use and accommodate other values. Alternative stocking standards for fire in the Wildland Urban Interface, mixedwood stands in the Cariboo and hardwoods on the Coast are some examples. Further supporting research and guidance would assist managers in developing stocking standards that can incorporate other non-conifer values.

Timber supply

Constraints on the use of glyphosate may result in netdowns of productive growing sites or reduced plantation performance which can impact timber supply. Bans on glyphosate use in Quebec and Nova Scotia have resulted in reduced stocking and challenges managing plantation where the objective is to maximize wood production.

Soil and water quality

The acute risk of glyphosate to terrestrial and aquatic wildlife has been found to be low when used according to the label. Changes to wildlife use of a block are related to changes in vegetation cover.

Non-target species

Vegetation complexes recover within a few years after application. Species richness and diversity was not found to be affected by glyphosate treatments.

Deciduous

Analysis of deciduous inventory at free growing from RESULTS showed an average number of deciduous stems/ha in a survey polygon after ground-based and aerial spraying was 449 and 504 stems/ha, respectively. The SBS zone (the most sprayed BEC zone) has an average of approximately 500 stems/ha of deciduous components at free growing. The results suggest that aspen stocking does recover after spraying and contribute to biodiversity.

The amount of deciduous mixed stands at free growing increased from 2,811 ha before harvest to 55,614 ha in the Northern Interior Forest Region for all reporting periods in RESULTS (BCMFLNROR 2008). Similarly, in the Southern Interior Forest Region deciduous mixed stands increased from 1,202 ha before harvest to 37,268 ha at free growing.

Aquatic

Numerous whole ecosystem field experiments in Canada have shown no direct effects on larval amphibian survival, growth, or development, the expression of genes related to larval development , or juvenile amphibian survival. Various Canadian studies on surface water glyphosate residue have found no detectable glyphosate or AMPA, the breakdown product of glyphosate, cpost-treatment when using buffers of l00 m for aerial and 10-60 m for ground applications.

Wildlife

Studies suggest that species richness and diversity of small and large mammals (with the exception of moose), songbirds and invertebrates remain within the range of natural variation and that changes are transient (Sullivan and Sullivan 2003).

Climate change

Maintaining healthy, resilient and productive stands can ensure that trees are robust in the face of climate change. This could be facilitated by maintaining a diversity of age classes and species. Vegetation management including glyphosate application can impact stand-scale and landscape-scale species diversity. However vegetation management is one part of forest management and there may be greater impacts to diversity from harvesting and reforestation methods

Carbon

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).

Structurally complex forests are better at carbon sequestration (Gough et al 2019). Mixedwoods stands may have a higher yield than either pure spruce or pure aspen stands (McCulloch and Kabzems 2009).

Wildfire

The use of glyphosate on deciduous trees has raised concerns that the risk of wildfire could increase. Where forest stand conditions should be maintained to achieve fire management objectives, fire management stock standards should be applied. Deciduous stems often act as natural fire breaks and are often used in fuel breaks to protect communities. Fires in deciduous stands are usually slow moving and easy to suppress.

The effect on fire behaviour from deciduous vegetation treated with glyphosate is not well documented. It is expected that the fire hazard from manual or chemical treatment would be high. ...

First nations

As stewards of the land, many First Nations are concerned about the effects of chemicals on all aspects of the environment. Some First Nations have very strong concerns. Education is important. Forest companies benefit from listening to First Nations and learning from their concerns. Licensees report that good engagement can often resolve issues but it may not be possible to satisfy everyone. First Nations that have good planning relationships can usually deal with issues in an appropriate way.

Public use

The impacts of glyphosate use on wildlife, soil, water and plants have been thoroughly studied and deemed to be relatively benign by Health Canada PWRA. There are ongoing concerns about the long term effects of low levels of glyphosate persisting in the environment. Recent studies by Wood (2019) found unexpected high levels of glyphosate residue in plants a year following silviculture treatment with glyphosate. More research is required on the long term, low-level persistence of glyphosate to understand the impacts on ecosystem health. Managers should work with plant users so they are aware of the potential for glyphosate persistence and take steps to minimize potential risks.

Recommendations

- Many of the issues concerning glyphosate are vegetation management and forest management issues. The degree to which values are managed or objectives are achieved should be considered at a broader scale to assess whether glyphosate is an appropriate tool. Concerns regarding timber supply, biodiversity, resilience to fire, pests and climate change are still pertinent with other vegetation management alternatives and may be best addressed through linkages to landscape level plans and cutting permit development.

- Further research and guidance is required on mixedwood stocking standards for different ecological site series. How much broadleaved stocking is acceptable for different objectives?

- Linkages of high-level plans to stand level plans could be improved. There are many competing objectives on the landscape (economic; biodiversity; wildlife; resilience for wildfire, forest health, climate change, etc) which can be challenging to balance at the stand level. The treated areas are relatively small. Perceived issues with glyphosate at the stand level may be alleviated at the landscape level.

- What is the impact of glyphosate on stand development? An improved understanding of the spatial distribution and growth of broadleaf species over time following harvesting would aid in understanding how objectives for biodiversity and resilience are being achieved.
- What is the impact of not using glyphosate? In many parts of the province herbicide use has been minimized or abandoned due to public and First Nation pressure. There is a trend toward declining brushing. Further analysis is recommended on the effects of suboptimal vegetation management on stocking and timber supply.
- How can vegetation management be improved to meet management objectives such as timber supply, carbon sequestration, biodiversity, and mitigate stand vulnerability to fire, insects and drought? Further research and monitoring post-harvest could guide vegetation management decisions.
- More data is needed for to update fire behaviour models which could influence vegetation management to reduce wildfire risk.
- More data is needed to understand the impacts of vegetation management on wildlife. Are silviculture treatments negatively impacting forage and habitat?
- Continued studies on long-term effects of glyphosate on plants, animals, soil and water are required to provide assurance that practices are not detrimental.
- Further research is required to understand the timelines that glyphosate can persist in plants. Persistence is related to climate and ecology. It may be possible to develop tools to assess the level of persistence.
- Glyphosate is the most studied herbicide in the world. The science regarding impacts to human health and the environment continues to be controversial. Glyphosate use is highly regulated in Canada and BC. Good herbicide practices are established in BC forestry and risks are managed in a manner consistent with the quality of stewardship that is documented with certification programs in BC. Glyphosate use continues to decline due to social pressure and administrative burden. Detractors' claims such as glyphosate eliminates broadleaf trees and contaminates water sources are not well supported, but continue to gain unchallenged acceptance. Best practices that are consistent with integrated pest management or integrated vegetation management provide a suitable framework for the judicious use of glyphosate where managing for timber production.

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