Evaluating the impacts of forest herbicide use on plant community diversity and structure: A review of the Alberta Biodiversity Monitoring Protocol

Report Prepared for the Alberta Herbicide Task Force

by

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Abstract

In response to a need for information on the effects of herbicide use in young plantations on plant community biodiversity in Alberta, the Alberta Lands and Forest Service and forest industry representatives developed a protocol that was intended to provide useful data. The protocol involves establishment and measurement by forest companies of paired plots within several of their herbicide-treated cutblocks . The design and the methods being used to acquire measurements under this protocol are examined in this report. Our examination involved field visits to five installations during July 2001, review and evaluation of the current protocol, discussions with individuals involved in establishment and measurement of these installations, discussions with other experts in this field, and current literature on this topic.

The basic design is consistent with requirements for a randomized complete block design which provides an effective way to obtain data on the effects of operational treatments. However, in addition to organizing the matrix of installations by Ecological Subregion and Ecosite, consistent site preparation and planting regimes should be applied to groups of sample installations in order to minimize uncontrolled sources of variation within matrix cells. For reasonable analysis we recommend working towards establishment and measurement of at least 6 installations in each matrix cell (with each cell representing a combination of complex and Site Preparation treatment).

Major problems and concerns identified in the existing installations and data include: 1) Plot pairs do not match ecologically; 2) The current small number of vegetation sample plots and their small size is not sufficient to adequately characterize the treatment plots (species are missed and cover is not accurately estimated); and 3) Field staff collecting data must have sufficient training and experience to be able to correctly identify all vascular plant species.

We recommend the following:

A.) Maintain the existing paired plot (Randomized Block Design) approach.

B.) Develop and review the sample matrix and determine which combinations of vegetation complexes, Ecological Subregions, ecosite, site preparation treatment, and crop species should receive priority for sampling. We recommend for simplicity a focus on the major complexes of competing vegetation (ie. the aspen-bluejoint complex) which are being controlled, and selection of a limited range od site preparation options (ideally no site preparation).

C.) Visit and examine the existing installations that were not previously visited to determine whether treated and untreated plots are ecologically similar and discard those that are not.

D.) Plan remeasurement of all suitable existing installations that fit in the priority matrix at age 5 or 6 (using a modified sampling protocol and have trained staff collecting vegetation data – Item G, H and I), in order to provide consistent long-term data on herbicide treatment effectseffects.

E.) If required, establish additional installations to provide a minimum of six (ideally 10 or more) useable replicate installations for each cell in the sample matrix.

F.) For any new installations assignment of treatments to plots must be done randomly

G.) Revise the measurement protocol to require: a) establishment and assessment of 25 subplots (2 m x 2 m for shrubs, herbs and grasses and 3 m x 3 m for small trees) for assessment of % cover and height of all vascular plants and ferns; b) collection of vegetation data during the peak of vegetation development (July to mid-August); c) photographs of each subplot as a basis for standardization and calibration; and d) Focus on collection of year 6 data from established installations, with collection of data during the following years being considered: pretreatment, 1, 2, , 5, and 10 years post treatment.

H.) Require that staff collecting data have the necessary qualifications and training in plant identification.

I.) Ensure consistency in estimation of percentage cover and other assessments by calibration and training of observers and/or through limiting the number of observers collecting data.

J.) Provide regular and ongoing analysis and reporting of results.

K.) Add treatments such as repeated application (two applications) of glyphosate, or other frequently applied treatments, to the matrix.

L.) Establish a small number of "experiments" where all treatments are replicated 6 or more times on a single site, using research scale plots (eg. 30 m x 30 m or larger) to provide information of potential treatment effects under research conditions and to provide a study where experimental error is minimized and power is maximized.

M.)Formation of a vegetation management research cooperative, to coordinate this project and other related studies should be considered.

Introduction

While studies have been conducted elsewhere in Canada, there is limited published information on the effects of stand tending applications of herbicides on plant biodiversity in Alberta forests. A herbicide monitoring program was initiated in Alberta in 1996 in order to obtain data on the effects of operational herbicide treatments on plant community composition and diversity (Alberta Lands and Forest Service 2000). Monitoring installations comprised of paired plots were established in numerous selected cutblocks, with one of the plots left untreated and the other receiving operational herbicide treatment. Data on plant community composition and species abundance and on crop tree growth was recorded annually in each plot. Between 1996 and 1999, 54 monitoring installations were established in Alberta. The current protocol and its implementation are examined in this report. Recommendations for protocol modification essential to effective achievement of its stated objectives are provided.

Forest herbicide treatment effects on plant biodiversity

The Alberta Herbicide Task Force (1999) provides a review of the published literature relating to effects of glyphosate application on plant community diversity in boreal forests. The literature available for the boreal forest indicates that, while foliar application of glyphosate can have appreciable effects on the vegetation community during the first 2 or 3 years following treatment, the longer term effects appear to be a reduction in tall shrub and broadleaf tree abundance and some shifts in relative species abundances compared to harvested areas of the same age which did not receive herbicide treatment,. Glyphosate treatment can also result in reduced dominance of certain common species (e.g. *Calamagrostis canadensis*) which may lead to increased richness, and/or changes in the relative abundance of other species (e.g. Boateng et al. 2000, Biring and Hays-Byl 2000, Biring et al. 1999, Sullivan et al. 1998, Herbicide Task Force 1999). A review is provided in the following section of published literature from North American studies relating to the effects of silvicultural application of glyphosate herbicide as a foliar spray on plant community cover, composition and diversity in young clearcuts. In addition to these specific studies, several review papers are also available relating to this subject (e.g. Balfour 1989, Lautenschlager 1993a, 1993b, Lautenshclager et al. 1995, Lautenschlager and Sullivan 2002).

Ten years after site preparation treatment of a Boreal Mixedwood site in northeastern B.C. using glyphosate, Boateng et al. (2000) report reduced dominance of the tall shrub layer, associated with increased structural diversity and richness of the herb layer. They report that while total cover did not differ between treated and untreated, tall shrub and deciduous cover were significantly reduced in the treated blocks. Species diversity, calculated using Simpsons' and Shannon Index was not significantly changed by treatment. The Boateng study is one of the few to examine the power of the experiment. Differences larger than 15% change in cover of selected shrub species (*Rosa acicularis*), with β=0.30 were detected.

Twelve years after treatment of a boreal mixedwood site with glyphosate, Biring et al. (1999) noted a significant reduction in vegetation cover, aspen cover, deciduous tree density, tall shrub density, deciduous tree cover, and fireweed cover compared to that in untreated. In addition, they report a shift in the dominant species, with willow dominating the tall shrub layer in plots that received herbicide treatment while alder dominated the untreated plots. Glyphosate treatment significantly increased the number of herbs and bryophytes but did not influence the

number of shrub species and significantly increased values of the Shannon-Weaver diversity index.

Twelve years after application of glyphosate as a site preparation treatment on a boreal mixedwood site near Stewart Lake, B.C. glyphosate treatment had appreciably reduced balsam poplar density and cover, but had little effect on willow density (Harper et al. 1997). Glyphosate treatment had no effect on species richness or diversity at age 12. While treatment did not significantly alter total cover, tall shrub cover was significantly reduced, and herb cover increased (though not significantly) compared to untreated plots. Glyphosate treatment resulted in a significant reduction in cover of forage species, with treated plots having approximately half of the forage cover found in the untreated control.

Four years after application of glyphosate, cover of blueberry species was reduced significantly compared to untreated on a boreal forest site in northwestern Ontario (Moola et al. 1998). In this study, three years of herbicide treatment resulted in nearly complete removal of blueberries.

Biring et al (2000) present data from tenth year measurement of the effects of glyphosate herbicide treatment to an aspen dominated site in the Sub-Boreal spruce zone near Fort St. James, B.C. Ten years after treatment, birch density was significantly reduced ($p=0.07$), conifer cover was significantly increased ($p=0.02$) and herb cover was significantly increased ($p=0.008$) in the treated plots compared to untreated. Glyphosate treatment resulted in sizable but non-significant reductions in cover of broadleaved trees ($p=0.16$) and shrubs ($p=0.11$). Treatment had no effect on total cover or species richness.

At another similar site in the Sub-boreal spruce zone, near Tsilcoh River, Biring and Hays-Byl (2000) found that while total cover and shrub layer cover had not changed significantly, cover of conifers and herbs was significantly increased ($p=0.06$ and 0.09 respectively), and cover of aspen was significantly decreased ($p=0.003$) ten years after treatment with glyphosate.

At two sites in the Sub-boreal spruce zone near Prince George, B.C. Sullivan (1994) found that herb layer biomass and cover was reduced for two years following treatment with glyphosate, but equaled or exceeded cover in untreated plots in the third year. At one of the two studied sites, shrub layer cover was also reduced by herbicide treatment for three years. Sullivan et al. (1996) report reductions in shrub layer volume for five years after treatment and temporary reductions in herbaceous vegetation "volume" during the first year after treatment. They also report that treatment of shrub-dominated communities resulted in reductions in shrub species diversity. In another study conducted near Prince George, Sullivan et al. (1998) found that glyphosate herbicide treatment caused a small reduction in herbaceous crown volume during the first year, but had no significant effect on herbaceous crown volume over four subsequent years. Treatment did not influence species richness or diversity in the herb layer. In contrast, herbicide treatment caused a significant reduction in shrub crown volume, and species richness that lasted for the five years of measurement. No significant effects of treatment on diversity indexes (Shannon-Wiener or Simpsons) were detected for either shrub or herb layer vegetation.

Freedman et al. (1993) report large initial decreases in vegetation cover during the first year following treatment of clearings in Nova Scotia with glyphosate, however no species were eliminated by treatment. During the subsequent two to three years there was substantial recovery

of vegetation cover. This caused an initial shift from shrub domination prior to spraying to communities dominated by perennial herbs and grasses.

Santillo (1994) and Santillo et al. (1989) present results from a study conducted in north-central Maine. They found that glyphosate treatments significantly reduced shrub cover and grass cover and species richness during the first three years after treatment and reduced cover of major browse species during the first five years. Raymond et al. (1996) report a significant decrease in total deciduous tree biomass (browse) during the first two years after glyphosate treatment, but no significant differences in total deciduous biomass seven to eleven years after treatment. They did observe species shifts, with biomass of willow and aspen being greater on treated and biomass of maples and yellow birch being greater on untreated areas seven to eleven years after treatment.

Following glyphosate application on a seven year old clearcut in central Maine dominated by aspen, birch, raspberry, pincherry, red maple and willow, there was an immediate decline in vegetation cover, particularly woody shrubs, with total cover, tall shrubcover and tree cover still remaining significantly lower in glyphosate treated than in untreated plots at age 9 (Newton et al. 1989, 1992).

Data from three fireweed dominated sites in the Engelmann-Spruce Subalpine Fir zone of southern British Columbia, showed significant reduction of fireweed cover and height for 5 years following treatment with glyphosate (Simard et al. 2001). Glyphosate reduced total cover and shrub cover for 5 years and herb layer cover for only one year following treatment. Glyphosate treatment did not have a significant effect on species richness or diversity.

On loblolly pine sites in Georgia plant community diversity at the end of 4 years was higher in herbicide treated than untreated (Edwards and Shiver1993). On another site, Boyd at al. (1995) found no effect of glyphosate treatment on species richness or diversity index values (Shannon-Wiener or Simpsons') 7 years after treatment.

While these existing studies indicate the potential for dramatic short term effects of foliar glyphosate treatment on plant community diversity at the stand level, long term effects appear to involve some reduction in abundance of deciduous trees and shrub cover. Additional studies are suggested to evaluate treatment effects in the Boreal forests of western Canada, and in particular to evaluate the potential effects of the use of glyphosate to control *Calamagrostis canadensis* (Herbicide Task Force 1999), and the potential effects of two applications of glyphosate during the first five years of plantation establishment.

Measures (indicators) of biodiversity

A variety of measures can be used to describe the overall diversity of plant communities. Species richness (the number of species present) is a widely used index of diversity because of its ease of interpretation and application to field situations. Its application requires accurate assessment of the number of species (Peet 1974) for the entire community and/or within particular structural or functional species groups. Richness can be analyzed for all strata (layers), or for each of the grass, herb, shrub and tree layers separately. When examining treatment effects on richness it is important to also consider changes in species composition, invasion of sites by weedy species, and the importance of rare species. A variety of modifications of

richness can be used in analysis, including species loss between paired untreated and treated plots, and estimation of richness based only on non-invasive species.

Diversity assessment should also consider the distribution of species abundances (which is often termed equitability) (Peet 1974, Pielou 1966). Because it is difficult to account for simultaneous changes in the number and abundance of several species, a wide variety of indexes have been proposed for measuring overall differences in plant community diversity. Simpsons Index (Simpson 1949) and the Shannon (Shannon-Wiener or Shannon-Weaver Index) (Shannon and Weaver 1949) are two indexes of community heterogeneity that are widely used in forest plant communities. Simpsons Index measures the probability that two individuals selected at random from a sample will belong to the same species and is sensitive to changes in abundance of the most abundant species in the community (Peet 1974). For a finite sample size Simpson's index is calculated as:

$$L=\sum[n_i(n_i -1)/[N(N-1)]$$

where n_i is the cover of individuals in layer i, and N the total cover.

In this formulation it should be clearly noted that L declines as heterogeneity increases, (or the lower the value of L the lower the likelihood of selecting individuals of the same species on repeated draws of a sample). Consequently Pielou (1966) recommends subtracting L from its maximum possible value of 1. [D=1-L].

The Shannon-Weaver Index (Shannon and Weaver 1949) is based on information theory. This index reaches a maximum with large numbers of species that are evenly distributed (Peet 1974, Pielou 1966). This index is sensitive to changes in rare species (Peet 1974). The index value can be calculated as:

$$h'=-\sum(n_i /N)\mathrm{Log}(n_i /N)$$

where n_i is the cover of individuals in layer i, and N the total cover.

Although widely used, few studies show significant effects of herbicide treatments on diversity measured using either the Simpsons or the Shannon-Weaver Indexes (Boateng et al. 2000). In seral forest communities in boreal forests, species abundances are typically uneven, with a small number of species being abundant, and several species having low cover values. For this reason, analysis of the effects of silvicultural practices on plant community diversity should examine changes in % cover of each of the major strata, % cover of common species, % cover of indicator species (or species of particular interest), and species richness, as well as these diversity indexes. Further development and testing of alternative diversity indexes may also be warranted. It would also be informative to obtain comparative data on plant community diversity prior to harvesting of these stands.

Methods for quantifying treatment effects

Determining whether herbicide treatment influences plant community composition and diversity requires testing of the null hypotheses that there was no significant effect of the treatment. Testing of hypothesis requires use of an appropriate experimental design. Major issues that need to be considered in experimental design are randomization, replication, sample sizes, and the power of the experiment. In any experiment, it is essential to have each treatment replicated at least 3 times, with random assignment of treatments to experimental units (ie. treatment plots) in order to avoid bias. Establishing designed experiments provides an ideal approach for determining the potential effects of a herbicide treatment on plant community diversity. Pseudo-

replication, which involves making comparisons between a single treated and untreated plot by treating samples taken in each of the two plots as replicates, is frequently encountered in forestry literature and has been used in several studies of herbicide effects on plant community diversity. The use of pseudo-replication is not acceptable since the samples taken within the plots do not truly represent replicate experimental units (ie. treatment combinations) but are only sub-samples within a single experimental unit.

Replicated experiments on individual sites

Establishing a fully replicated experiment on a single site, with random assignment of treatments to experimental units is ideal since it provides an opportunity to minimize uncontrolled (ie. error) variance. For such studies, treatment plots are typically in the order of 100 (10 m x 10 m) to 1000 (33 x 33) m^2, to allow for establishment of treated buffers around a central measurement plot. If variation is encountered within the site, the study site can be subdivided into blocks, resulting in a randomized block design. Within experiments of this nature, replication is achieved by applying each treatment to three (or ideally five or more) treatment plots, with treatment assignment being done randomly for the entire experiment (completely randomize design) or within blocks (randomized block design).

Two crucial questions arise with reliance on experiments that are conducted in this way. First, the application of results to other similar sites is not guaranteed, and consequently further testing should be undertaken to evaluate the general application of results from such an experiment. Second, the small size of treatment plots typically used in experiments results in treatments being more consistently and uniformly applied than is often the case with operationally applied treatments. Treatments applied for research purposes typically have greater effects on vegetation (ie. higher levels of vegetation control) than those applied for operational purposes (Simard et al. 2001). Consequently, effects on plant community diversity may be larger under such circumstances. Two major advantages to such studies are: 1) efficiency of data collection and lower travel costs since all work is concentrated on one site, and 2) greater control of potential sources of variation and reduced error variance (which should increase the ability to detect treatment effects).

Monitoring

In order to examine the effects of operationally applied treatments it is necessary to use large (1 hectare or larger), treatment plots. In the case of aerial herbicide treatments, larger treatment plots are required in order to ensure that typical operational treatments are represented and to deal with edge effects and variability within the treatment plots. The ideal size of a treatment plot will depend on the spray equipment being used. In Alberta, the Herbicide Task Force (2000) recommends a minimum size of 2.5 hectares. This appears to be a realistic minimum size for untreated plots, and will provide an adequate buffered area for sampling. For ground based herbicide application this should also be a reasonable size while for aerial herbicide application, treated "plots" will likely need to be substantially larger than this minimum size.

With plots of this size, it can become difficult to find sufficiently large uniform areas for the establishment of a fully replicated experiment on a single site – for two treatments (ie. an untreated "control" and a glyphosate herbicide treatment), with 4 replicates of each treatment – requires a total of 8 treatment plots (2 treatments x 4 replicates), which requires 12 hectares. This 12 hectares would have to be reasonably uniform, so that site variation and other factors do

not seriously influence the vegetation. Except where very large and very uniform cutblocks are available for such studies, it is difficult to find suitable homogeneous sites. Even then, questions will remain regarding the general applicability of results obtained from the one study site to the whole population of sites being treated operationally.

An alternative approach, which is described in many statistical textbooks (Hicks 1973) as an option which may be used when replication of treatments is not possible within a single field, is to consider each cutblock available for the study as an individual block within a randomized block design. With this design, each treatment being compared is replicated one time in each block and several replicate blocks are established to provide replication and to permit statistical analysis. A further requirement is that the allocation of treatments be done randomly within each block. Using this approach, it is possible to accommodate large treatment plots within available sites. Also, by obtaining data from several cutblocks distributed over a larger area and range of conditions, there may be greater confidence in the general applicability of the results.

Using this design is likely to require more replicates than is the case with a simple completely randomized design applied to a single site, in order to deal with the degrees of freedom lost due to blocking, and in order to accommodate the larger amount of uncontrolled error variance resulting from the use of several sites.

In experimental design, substantial attention is often devoted to minimizing the chance of incorrectly stating that there is a treatment effect when no effect exists. This is termed a type I error (Zar 1974). Type I error is minimized by having adequate sample size, and is defined in terms of the value of α. Less attention is typically given to the chance of incorrectly concluding that there is no treatment effect when there is in fact a treatment effect (Type II error). The probability of a type II error is β. Type II errors are reduced by having sufficient replication and by minimizing error variance (due to sampling and measurement error). Power analysis can be utilized to estimate sample sizes required to achieve desired levels of sensitivity and confidence (Nemec 1991). For the purposes of documenting treatment effects on plant community diversity, it is important to minimize type II errors and to understand the underlying power of the analysis.

Sampling

A further issue that is important to reducing uncontrolled error is the accurate and consistent measurement of response variables. For this purpose the size of the sample used to measure responses within each treatment unit must be appropriate and methods used must be accurate and consistent. In addition, samples should not be taken too close to the edges of the treatment plot, in order to avoid possible influences of the adjacent area and possible differences in treatments near the edge of the treatment plot.

In order to ensure that all species occurring within the treatment plot are documented a suitable area must be sampled. A range of plot sizes have been used in other studies: Sullivan et al. (1998) and Lindgren and Sullivan (2001) use 25 1 m x 1 m plots for the herb layer, 25 2 m x 2 m plots for the shrub layer, and 25 5 m x 5 m plots for the tree layer. This involves sampling a total of 25 m^2, 100 m^2, and 625 m^2 for herb, shrub, and tree layers. In the Procedures for Operational Brushing Evaluation (PROBE) protocol (Simard 1993) vegetation data is collected either in small plots centered at each of 36 sample trees or in four 50 m^2 (200 m^2) plots (). For the Experimental Design Protocol for Long-term Response Evaluation (EXPLORE) protocol, herb and shrub vegetation is evaluated in four 50 m^2 (200 m^2) plots (Biring et al. 1998).

Species-area relationships are commonly used in the ecological literature to determine minimum areas to be sampled. Figure 1 shows that, for an untreated area, on an "e" ecosite (Beckingham and Archibald, 1996), in the Boreal Mixedwood subregion, the number of species continues to increase as area sampled increases up to at least 15 m^2 (fifteen 1 m x 1 m plots), the number of grass and shrub species appears to level off at approximately 13 m^2 (thirteen 1 m x 1 m plots).

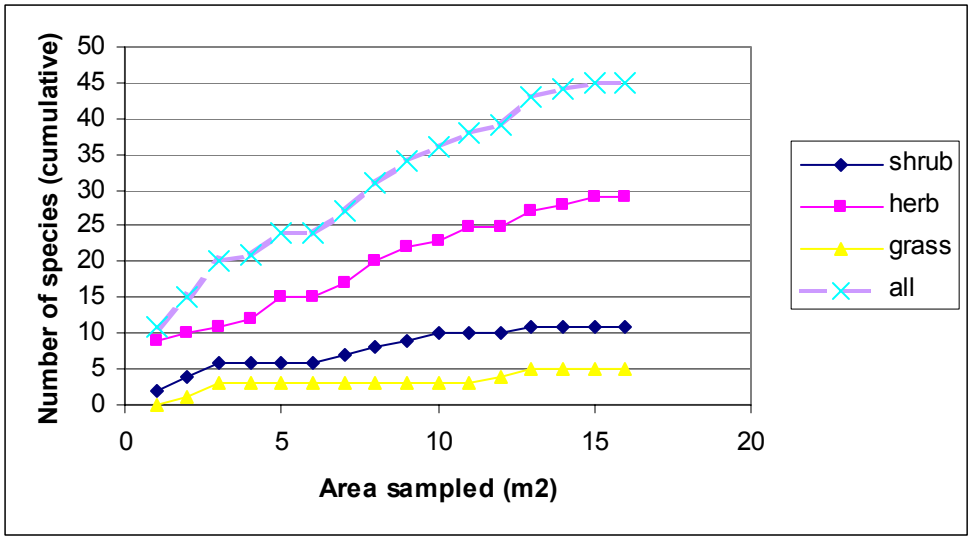

Figure 1. Relationship between cumulative total number of species recorded and cumulative area sampled for an untreated plot in one HTF monitoring installation located on a Boreal Mixedwood e ecosite, near Slave Lake, Alberta

Table 1. Statistics used to estimate sample size requirements using 1 m x 1 m plots for evaluating % cover of each layer. Sample size was estimated as described by Bergerud (1988) assuming a 20% allowable error and α=0.10.

layer	mean % cover	n	S	Estimated sample size
shrub	16	16	16.779	76.21855
herb	25.1	16	21.4281	51.11984
grass	10.6	16	21.4309	278.2127
total	51.7	16	31.1056	26.33869

Another consideration is the sample size required to adequately determine the mean cover of each vegetation layer and of each species. Based on the sample of % cover data for sixteen 1 m^2 sample plots , 76, 51, 280 and 26 plots would be required to estimate average percent cover within 20% of the mean for the shrub layer, herb layer, grass layer and total, respectively.

Samples must also be representative and have an unbiased distribution in the treatment plot, avoiding (or documenting) anomalous microsites (ie. ruts, skidtrails, large stumps, …). If a rigid systematic approach to sampling is used, then major micrositefeatures should be documented in order to isolate anomalies such as skidtrails, ruts or other features from analysis or to qualify results of analysis. and a larger sample size may be required in order to accommodate such anomalies. While a large random sample may be desirable, random sampling may result in a poor distribution of samples through the treated plot. For this reason, systematic grids or transects are commonly used, with the assumption that there are no regular patterns of vegetation within the plots that might conform to the same pattern as the sample grid. We recommend use of a systematic grid – with collection of data from at least 25 small plots. Minimum sample plots sizes should be 2 m x 2 m for herbs, and shrubs in order to provide a total sampled area of 100 m2 within each treatment plot.

Evaluation of treatment effects on plant community composition requires that complete and accurate lists of the species present in each plot are obtained. This is particularly critical in areas where diversity of the native flora is low, such as in the boreal forests of Alberta. Mis-identification of species or failure to document the presence of species will render all results useless. Reducing these errors requires both adequate sample size and the use of properly trained observers.

Observers collecting data of this sort should have botanical training and be able to accurately identify plant species using available keys (reliance on available picture books is not acceptable). Ideally they should have detailed knowledge of the local flora. Dealing with some taxa, notably willows, grasses, sedges, rushes, and asters requires the ability to recognize differences in the field. When specific identification is not possible in the field, specimens should be collected for identification in the lab (with assistance of experts on certain taxa on occasion).

Measures of species abundance must be consistent and repeatable. Visual estimates of % cover are widely used in studies of forest plant communities even though variation between observers is high. To ensure consistency, common practice is to have all data collected by a single observer. An alternative is to provide training and cross-calibration to ensure consistency between different observers. While line intercept techniques could be used as an alternative to

visual estimates of percent cover this method does not work well for the less abundant species that are not uniformly distributed within sample subplots.

Description of current Herbicide Task Force Protocol

(Alberta Lands and Forest Service, 2000, see Appendix A).

The 2000 protocol indicates a desire to establish replicate samples within a matrix of selected ecosites. Because selection of cutblocks to be sampled had been left to individual companies, organization and utilization of a matrix does not appear to have been consistently achieved. Table 2 provides a summary of the number of installations established for each of the sampled ecosites. Small numbers of installations (3 or fewer) have been established for five of the nine matrix cells listed. Data analysis requires establishment of 3 or more installations for each cell. Ideally, six to ten replicate installations is desirable.

Table 2. The current matrix of installations organized according to subregion and ecosite. (Ecosite information was available for only 40 of the existing 54 installations.)

		Establishment Year					
Subregion	**Ecosite**	**1996**	**1997**	**1998**	**1999**	**2000**	**TOTAL**
Boreal Mixedwoods	b	1					1
Boreal Mixedwoods	d		4	7	4		15
Boreal Mixedwoods	e	1	1		3		5
Boreal Mixedwoods	h		1				1
Lower Foothills	c		1	1			2
Lower Foothills	d				2		2
Lower Foothills	e		1	1	4		6
Lower Foothills	f	2	2		1		5
Upper Foothills	e	1	1		1		3
TOTAL		5	11	9	15		40

Within selected blocks, two 2.5 hectare plots with similar site characteristics (i.e. variability in site characteristics within the two units should be similar) are selected. The protocol specifies that the two plots should be ecologically similar and have similar topography, drainage, elevation and pre-harvest timber type, as well as being in the same soil moisture regime class. Herbicide treatment is applied to one plot, while the second plot is used as an untreated control plot. The protocol does not currently specify that the selection of the treated plot should be done randomly.

Species present and the percent crown cover of each species is recorded in fifteen sample plots located along a single 30 m long transect installed in each treatment plot (Figure 2). Sample plots are 20 cm x 50 cm for herbs and grasses, and 1 m x 1 m for shrubs (<2.5 m tall). A single 10 m x 10 m sample plot, located at the transect midpoint, is used for tall shrubs (>2.5 m tall) and trees. Vegetation data are to be collected from these sample plots annually from pre-treatment until age 5.

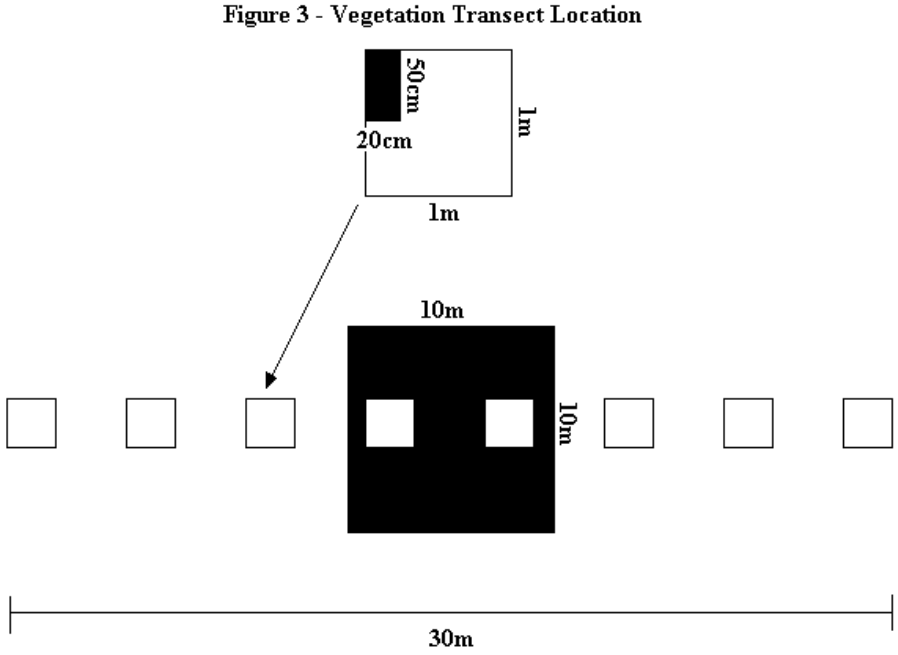

Figure 2. Layout of vegetation assessment plots along the sample transect in the current Herbicide Monitoring Protocol (from Alberta Lands and Forest Service 2000).

Evaluation of the Herbicide Monitoring Protocol (Alberta Lands and Forest Service 2000)

Five installations were visited in early July 2001. A detailed examination of the existing datasets was completed including a discussion of issues relating to the design, establishment, and measurement of these installations with individuals involved in using the current protocol and with other experts. Major problems with the current protocol and its implementation are:

1) Pretreatment or ecological differences between treated and untreated plots in individual plot pairs.

Two of five sites visited were not homogeneous (treated and untreated plots were not ecologically similar), and examination of the collected data for the time prior to treatment indicates that a small number of other installations had pairs of plots that had significantly different species composition prior to treatment

2) Insufficient sample size and subplot size within treatment plots.

Current sampling involves assessment of herbs and grasses in a total area of 1.5 square meters in each of the treated and untreated plots (15 subplots each with an area of 0.10 square meters). In our examination of the area within and immediately adjacent to established transects we found numerous species that were not included on the species list for the plot. The area currently being sample is insufficient for documenting herb and grass cover. A total sample of 50 to 100 square meters in each treatment plot is considered to be more appropriate for studies of this nature (Wayne Bell, Ontario Ministry of Natural Resources, Pers. Comm. November 2001).

3) Poor distribution of sample subplots within treatment plots.

Use of one transect of sample points provides a poor representation of the plot, given the heterogeneity of a typical cutblock. In one treated block, the transect of plots actually followed a skip in the treatment and at another site, the transect of plots followed a set of wheel ruts. Sample points should be established in representative portions of the treatment plots and should be established in an unbiased fashion.

4) Need for description of microsite features in each sampled subplot.

With the use of systematic sampling, individual subplots land on a range of microsites. When these fall on non-representative microsites (ie. skidroads, ruts, stumps, etc), it is useful to be able to identify their contribution to the data when it is being analyzed. Failure to document microsite features at individual sample points precludes the opportunity to evaluate and differentiate microsite influences.

5) Plant mis-identification and omission.

On several of the sites visited we noted species that had not been recorded on the data forms or that were incorrectly identified. This was due to both the small area being sampled in each treatment plot and to problems with observers plant identification skills. Missing species were often not in the original sample subplots, due to the small area sampled in each treatment plot. Misidentification of species of willows, grasses, sedges and rushes was also apparent and is likely related to training of observers, and to the timing of sampling in late summer (sampling in early to mid July would be preferable to sampling in late August or September; it may be necessary to visit these sites 2 or 3 times during the year).

6) Inappropriate or inconsistent timing of measurement.

Sampling times appear to be highly variable. Most sampling appears to have occurred in mid or late August. However, some contractors stated that they had collected data in September. Standardization of assessment time is desirable in order to reduce seasonal effects on cover and to ensure that species are not missed. The ideal timing for assessments is probably at about the peak of vegetation development (generally early July through mid-August). This is likely to be the optimal time for identification of most species and for evaluation of percent cover. It may be necessary to revisit some sites, on occasion, in order to collect fruiting bodies or other material required for accurate identification of certain species.

7) Incorrect assignment of species to identified strata.

Incorrect assignment of species to strata was observed during the analysis of the dataset. This resulted in incorrect sample plot sizes being applied. For this reason use of a single standard sized subplot may be desirable. In addition, data on the modal height of each species should be recorded so that such errors can be resolved.

8) Lack of information required for thorough evaluation of community structure

Evaluation of structural changes in plant communities requires more detailed information on height of each species, in order to permit evaluation of more detailed structural classes. The current protocol does not include measurement of height of each species. A record of modal height of each species would also be useful for calculating "canopy volume" and for estimating forage and browse biomass.

9) Other undocumented sources of variation.

Differences in time since harvesting, site preparation treatment, crop species and other factors exist between installations. There needs to be sufficient replication of ecosite, site preparation, crop species and time since installation in order for meaningful analysis to be completed. A minimum of four replicates for each site preparation and crops species combination, for each eco-site, would be desirable. Reducing, controlling, and/or accounting for variation in these factors would substantially improve the statistical power of the results from this work.

Recommendations

The basic design, which utilizes a randomized block design with a pair of plots established in each block (installation) has the potential to provide valuable information on the potential effects of operational application of glyphosate herbicide (or other treatments). Remeasurement of many of the existing installations could provide useful and valuable information on the effects of glyphosate herbicide treatments on plant community diversity in a timely fashion. A clear advantage to remeasuring these existing installations is that data on effects at six or more years after treatment will be available much sooner than would be the case for new installations or studies. However, modification of the methods being used is required in order to provide credible and interpretable results. We provide the following seven recommendations:

A) Maintain the existing paired plot (Randomized Block Design) approach

B) Develop and review the sample matrix and determine which combinations of vegetation complex, Ecological Subregions, ecosite, site preparation treatment, and crop species will receive priority for sampling. Data collection should focus on the complexes and ecosites which most commonly receive herbicide treatment (these appear to be: d and e ecosites in the Boreal Mixedwoods Subregion; and ecosites e and f in the Lower Foothills Subregion). Focusing attention on a limited number of matrix cells may be desirable in order to ensure collection of high quality data and to control measurement costs.

C) Visit and examine existing installations to determine whether treated and untreated plots are ecologically similar and discard those that are not.

D) Plan remeasurement of all suitable existing installations that fit in the priority matrix at age 5 or 6 (using a modified sampling protocol and have trained staff collecting vegetation data – Item G, H and I), in order to provide consistent long-term data on herbicide treatment effects.

E) Establish additional installations to provide required replication for each cell in the sample matrix (and to deal with installations that are discarded). The target should be to establish at least 6 (and preferably 10) replicate installations (with similar site preparation treatments and with the same crop species) for each ecosite. (The ideal sample size will be determined upon completion of power analysis of new data from these sites). For these and future plots there must be a formal analysis of whether the plot pairs are indeed similar ecosites and meet the criteria necessary for pairing.

F) For new installations assignment of treatments to plots must be done randomly

G) Revise the measurement protocol as follows:

i. Vegetation assessments (% cover and modal height estimates for each species) will be completed in 25 subplots established on a grid system for assessment of. 2 m x 2 m plots should be used for the shrubs, herbs, and grasses. 3 m x 3 m plots for small trees (<5 m) (Figure 3). For tree species a count of the number of stems should be recorded.

ii. Data should be collected during July and early August when vegetation is fully developed. Revisiting of sites may be required to collect fruiting bodies or other material for identification.

iii. Years for measurement: pretreatment, 1, 2, 3, 5, and if desired, 10 years post treatment. Minimum requirements are sampling at: pretreatment, and 2 and 5 or 6 years post-treatment. For existing installations the focus should be upon acquiring data at age 5 or 6.

iv. In the protocol provide expanded details on assessment procedures and provide comparison charts for estimation of percent cover.

v. Data collection is estimated to take approximately two to three days for a 2 person crew for each installation (1 to 1.5 days per treatment plot) (Based on personal communication with Tom Sullivan)

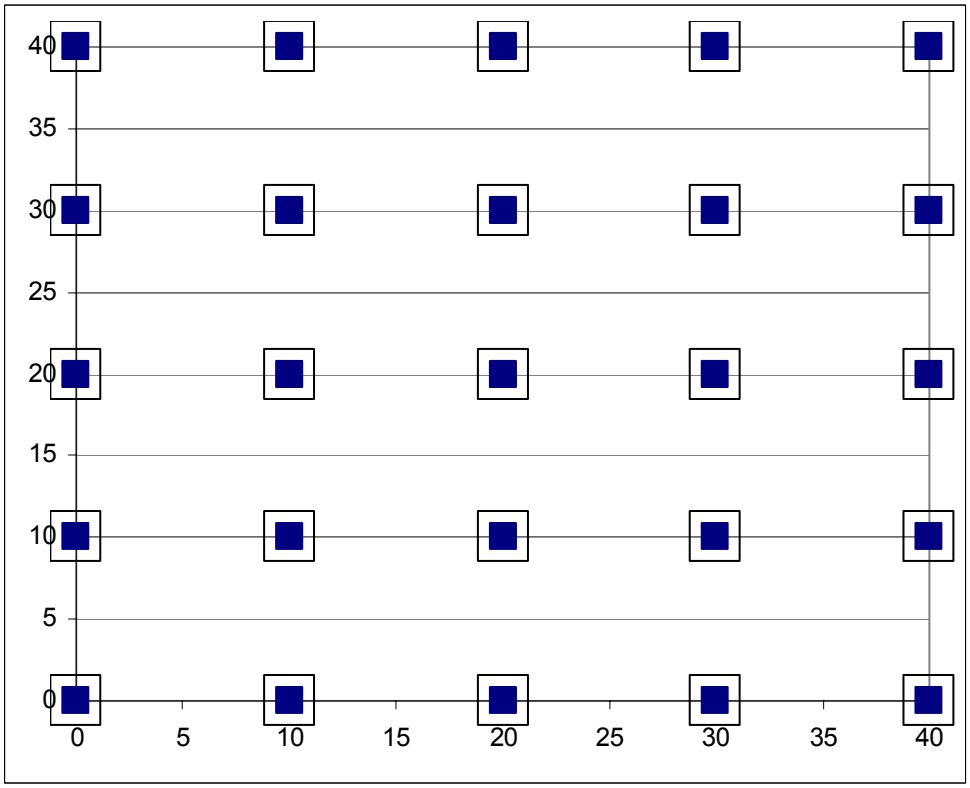

Figure 3. Recommended layout of 25 sample plots to be used for vegetation measurement. Note plot lines must not follow skid paths, in-block roads, treatment skips or other regular features in the block.

H) Data must be collected only by qualified and trained staff. Training must include formal courses in advanced plant identification and use of plant taxonomic keys.

I) To increase consistency, it would be ideal to have all data for installations in each matrix cell collected by the same individual. If this is not possible, increased effort must be invested in training and in standardization and cross calibration of data collected by different observers. Two or more photographs of each subplot should be

taken for standardization and cross calibration. The use of a digital camera is recommended for this purpose in order to facilitate labeling and cataloguing of the images.

J) Data must be analyzed and reported on a regular (annual) basis. Short reports should be provided summarizing updated results and work accomplished on an annual basis. Detailed reports should be prepared for publication in peer-reviewed journals, when sufficient data have been obtained to merit publication (e.g. sixth year data have been analyzed for at least 6 replicates in a matrix cell). To date, only preliminary analysis of most installations has been completed using ordination techniques. Complete analysis of data should be planned and conducted on a regular schedule. While ordination and cluster analysis have value for exploring trends in the data, the use of analysis of variance and repeated measures analysis to test for significant treatment effects on various measures (total % cover, % cover of individual strata, % cover of common and selected species, diversity indexes, etc.) is preferred for testing hypotheses regarding effects of treatment on plant community composition and structure.

K) The Alberta Herbicide Task Force should periodically review the treatment list, and consider adding treatments (or treatment combinations) that reflect current or anticipated future operational practices. Additional treatments could be incorporated into the current design. On some sites with severe competition, plantations receive two applications of glyphosate herbicide in order to provide sufficient control of competing grasses. We recommend that this treatment be evaluated on selected sites. Similarly, it may be desirable to examine other treatments such as basal bark application of triclopyr..

L) To complement data from these monitoring installations it would also be valuable to establish one or more fully replicated experiments on individual sites within selected complexes to provide detailed information on the effects of optimal herbicide applications (research type applications in small (30 m x 30 m plots)) on plant community diversity. Such a study could potentially compare several alternative treatments (ie. untreated, foliar vision applied once, foliar vision applied twice, basal bark application of triclopyr to aspen plus foliar vision application for grass and herb control, etc). Establishment and measurement of a single experiment of this nature should be expected to cost approximately $50,000 per year for years of activity (pretreatment, 1, 2, 3, and 5 years) for a total of approximately $250,000 over 6 years.

M) Formation of a vegetation management research cooperative, to coordinate this project and other related studies should be considered. Appointment of a program manager in connection with such a cooperative, could ensure continuity and consistency in data collection and provide resources necessary for program management, data management and timely reporting of results. Cost of a full scale program to acquire data on benefits and effects of herbicide treatments is expected to cost between $120,000 and $150,000 annually.

Sampling Schedule

Table 3 provides a summary of the annual re-measurement requirements based on sampling of the 31 installations established on Boreal Mixedwoods "d" and "e" eco-sites and Lower Foothills "e" and "f" eco-sites prior to 1999 at ages 4, 6, and 10. The number of field days to complete sampling is indicated (based on an estimated average of 2.5 days to complete vegetation assessments at each installation), and represents the number of days required for a two person crew to complete data collection. In addition, all existing installations need to be evaluated to ensure that the plots are ecologically similar and suitable for assessment prior to the next re-measurement.

The need to collect year 4 data should be carefully evaluated (with priority given to acquiring year 5 or 6 data). We recommend focusing on acquisition of year 5 or 6 data from the existing installations. If desired, some additional data could be collected at year 0, 1, 2, and 4 on more recently established installations. These estimates provide an indication of the potential magnitude of sampling requirements, with additional time required for establishing and measuring additional new installations, for completing identification of collected plant specimens, for data processing, data analysis, and reporting.

Table 3. Remeasurement schedule for the 31 installations established in the four major matrix cells (BMd, BMe, LFe, and LFf ecosites).

BMd	**Age**			
Year	**4**	**6**	**10 total**	
2002	4	0		4
2003	4	4		8
2004		7		7
2005		4		4
2006				0
2007			4	4
2008			7	7
2009			4	4
Total	8	15	15	38

Bme	**Age**			
Year	**4**	**6**	**10 total**	
2002	1	1		2
2003	3	1		4
2004				0
2005		3		3
2006			1	1
2007			1	1
2008				0
2009			3	3
Total	4	5	5	14

LFe	**Age**			
Year	**4**	**6**	**10 total**	
2002	1			1
2003	4	1		5
2004		1		1
2005		4		4
2006				0
2007			1	1
2008			1	1
2009			4	4
Total	5	6	6	17

LFf	**Age**			
Year	**4**	**6**	**10 total**	
2002	2	2		4
2003	1	2		3
2004				0
2005		1		1
2006			2	2
2007			2	2
2008				0
2009			1	1
Total	3	5	5	13

ALL	**Age**

Year	4	6	10	BM	LF total		Field sampling days
2002	8	3	0	6	5	11	27.5
2003	12	8	0	12	8	20	50
2004	0	8	0	7	1	8	20
2005	0	12	0	7	5	12	30
2006	0	0	3	1	2	3	7.5
2007	0	0	8	5	3	8	20
2008	0	0	8	7	1	8	20
2009	0	0	12	7	5	12	30
Total	20	31	31				

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Appendix A. Herbicide Monitoring Protocol (Alberta Lands and Forest Service 2000).

L. Operational Herbicide Monitoring Program

OPERATIONAL HERBICIDE MONITORING PROGRAM

1.0 Introduction

1.1 Background

Until 1994, forest herbicide use in Alberta was generally limited to small trials. This approach allowed forest managers and the public the opportunity to gain more experience and knowledge in the use of herbicides in forest management.

Forest industry and Land and Forest Service (LFS) staff, however, believed operational use of herbicides was required on some sites to enable legislated reforestation requirements and sustained yield objectives to be met. In 1994, the Minister of Environmental Protection approved new provincial guidelines that allow limited operational use. One of the conditions for use is that the proponent implements a herbicide monitoring program.

A committee of forest industry and government representatives developed a monitor program methodology that incorporates many existing LFS sampling procedures. The methodology requires monitoring plots to be established on both treated and untreated areas. This approach will provide an opportunity for measuring the successional changes in plant species composition and coniferous seedling growth response due to herbicide applications.

The monitoring process, while conducted in a scientific manner, is not as rigorous a methodology as a research project would require. It is instead a practical approach to gathering information on the effectiveness of herbicide use in achieving certain silvicultural objectives. This information will be useful in determining how forested lands in Alberta should be managed in future.

1.2 Purpose

The purpose of the Operational Herbicide Monitor Program is to provide information on the effects of operational silvicultural herbicide programs in Alberta.

The main objectives are as follows:

1. to quantify the effects of herbicide use on competing vegetation and on crop tree survival and growth.
2. to monitor the effects of herbicide use on plant species composition and abundance over time.

2.0 Monitor Site Selection

Site selection, plot location and establishment (and initial reading) must be completed prior to herbicide treatment.

2.1 Ecosite Matrix

At the provincial level, monitoring sites should be identified to complete a matrix of ecosites (moisture/nutrient regime). To minimize duplication, Alberta Land and Forest Service (LFS) will co-ordinate the completion of the matrix.

Ecosite will be defined in terms of site characteristics identified in the Field Guides to the Ecosites of Alberta, 1996. Initially, monitoring efforts will focus on frequently treated ecosites. Efforts should be made to assess a range of reforestation practices and herbicide prescriptions across these sites.

Reforestation practise will be defined by broad treatment class rather than by specific means; for example, raised planting site will be a component of practise rather than specific types of mounder. Large planting stock, rather than a specific container size or container/transplant regime, is another example.

2.2 Monitor Plot Intensity

Sampling intensity will be determined by frequency and scale of herbicide use. Sampling intensity will be revised as experience with both herbicides and monitoring increase; and as the monitoring plot location matrix is filled.

In 1998, each company that conducts an operational herbicide program greater that 100 ha must establish at least 1 monitor plot.

2.3 Field Site Selection

Monitor cutblocks will be selected based on the monitor plot location matrix. When the matrix is developed, proponents will consult LFS Forest Management Division before selecting the cutblocks, to determine which ecosite and reforestation practices should be sampled.

Within the candidate blocks, a minimum of 2, 2.5 hectare units with similar site characteristics (i.e. variability in site characteristics within the two units should be similar) should be identified. The units should be within the ecosite matrix (see section 2.1).

One unit will be treated as part of the operational herbicide program (treatment), the other unit will be left as an untreated, "control" plot. The division between the two units must be clearly visible and the integrity of each treatment must be ensured. For aerial herbicide programs, larger areas may have to be identified to enable appropriate treatment/control units.

Site characteristics should be as uniform as possible across the treatment/control units. The following factors should be considered when determining site suitability.

Topographic factors:
slope - level or uniform (+/- 10%)
aspect - uniform (within 45□)
position - crest, mid-slope, lower slope, toe or plain

Macro-drainage: avoid areas with ponding, stream channels

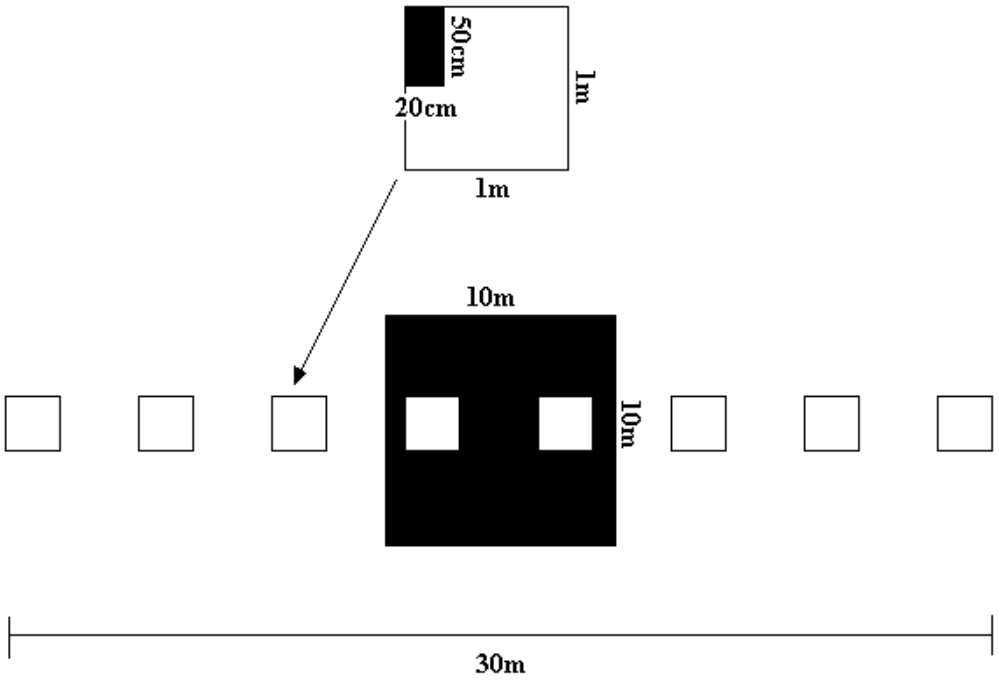
Soil moisture regime: same class (xeric, subxeric, etc.)

Soil textures: same broad class: fragmental, sandy skeletal, loamy skeletal, clayey skeletal, sandy, clayey or coarse frag. loamy content.

Elevation: variation less than 50 m

Pre-Harvest Timber type: same dominant species

Figure 3 - Vegetation Transect Location



3.3 Plot Measurement

Once identified measurement trees should be assessed as follows:

		Assessments	
Tree parameter	**Initial**		**Subsequent**
Species		Yes	No

Probable origin	Yes	No
Age	Yes	No
Total height (cm)	Yes	Yes
Leader length (0.5 cm)	Yes	Yes
Basal diameter (1 mm)	Yes	Yes
Competition type code	Yes	No
Competition height code (relative height)	Yes	Yes
Seedling condition code (see Appendix I)	Yes	Yes
Conifer Crop tree density	Yes	No
Seedling vigour code	Yes	Yes
Larger vegetation density	Yes	No

3.4 Assessment Techniques

Crop tree parameters identified above should be assessed as per Appendix 1. Remeasurements should be taken at the same time of year as the previous measurements to reduce variability.

4.0 Vegetation Transect Location

The purpose of collecting vegetation data is to determine if there is a difference in plant species composition between treated and untreated cutblocks and to examine the successional changes between the two treatments. The specific objectives include:

1. Compare species composition changes between cutblocks treated with herbicides and cutblocks left untreated and
2. To examine the successional changes of the two treatments over time.

4.1 Location

Locating the vegetation transect can be delayed until the crop tree response plots are established to ensure the transect represents the average vegetation characteristics of the sub-unit (and of the overall monitoring unit).

Vegetation transects must be placed in a representative part of the monitor site. The vegetation change monitoring transect will parallel the crop tree transect. However, transects located on slopes must be established parallel to slope contours. The vegetation and crop tree transects must be a minimum of 20 m apart to minimize damage to the vegetation. A transect must be 30 meters long with 15 microplots placed along the transect. At each location a 1 x 1 m microplot will be used to record the canopy cover of shrubs (<2.5 m in height) and a nested 20 x 50 cm microplot will be used to assess the canopy cover of forbs and graminoids. One 10 x 10 m macroplot located at the centre of the 30 m transect will be used to estimate the canopy cover of trees and tall shrubs (> 2.5 m in height). Trees and tall shrubs will only have to be recorded once in the average % cover column to the nearest 5%. See Figure 3 on Page 63.

4.2 Establishment Procedure

Drive a brightly coloured 1 m metal post well below the frost zone at the centre of each microplot placed along the transect. The post should be labelled with sub unit (treated/untreated) and plot number.

4.3 Plot Measurement

Cover estimates for all other species will be recorded to the nearest 5%; those between 0 and 5%, to the nearest 1%. Canopy cover estimates will be recorded at each microplot on the MF5 form. The plant species (trees, shrubs, graminoids and forbs) will be recorded using a seven letter code composed of the first four letters of the genus and the first three letters of the species (per Moss, E. H. 1983 Flora of Alberta.). If the species is unknown it will be marked on the plot sheet, collected and later identified. If possible all plants should have a species name. The species will be listed on the plot sheet in the following order: graminoids, forbs, shrubs and trees.

4.4 Data Entry

The mean canopy cover of each species over the 15 microplots (treated, untreated) will be entered on Excel or Lotus in the format outlined below. These files must be forwarded to the Land and Forest Service annually as required.

Spacing for Lotus or Excel file columns are: plot no=7 spaces, layer=2 spaces, species=8 spaces, cover=5 spaces, species=8 spaces, cover=5 spaces, species=8 spaces, cover=5 spaces, species=8 spaces, cover=5 spaces,

(7)	(2)	(8)	(5)	(8)	(5)	(8)	(5)	(8)	(5)
Plot no.	**layer**	**Species**	**Cover**	**Species**	**Cover**	**Species**	**Cover**	**Species**	**Cover**
lr96tr	7	festrub	25.2	Phlepra	26.3	poa pra	25.2	festsca	52.3
lr96tr	7	dantpar	0.3						
lr96tr	6	astelae	25.6	Taraoff	25.2	trifrep	1.2	galibor	5.2
lr96tr	6	geumtri	0.3	Antelan	2.5	astecil	2.1	trifpra	2.3
lr96tr	6	haledef	0.1						
lr96tr	5	rosaaci	2.0						
lr96un	7	phlepra	3.0	poa pra	0.3				
lr96un	6	galibor	2.0	Trifpra	25.0	taraoff	35.1	haledef	12.5

Where layer is:

1=trees
2=understory trees
3=epiphytes (tree lichens)
4=tall shrubs (alder willow)
5=understory shrubs (rose, raspberry)
6=forbs
7=grasses, graminoids
8=mosses

9=lichens

Note: do not exceed a total of 4 (species, cover combinations) per row (for example if you have 5 grass species enter 4 then start a new row for the fifth), start a new row for each layer (make sure the plot numbers are the same for the various layers).

4.5 Data Analysis

Classification

The data for each site will be analyzed using the multivariate analysis techniques of classification and ordination. Classification is the assignment of samples to classes or groups based on the similarity of species. A polythetic agglomerative approach will be used to group the samples. This technique assigns each sample to a cluster which has a single measure. It then agglomerates these clusters into a hierarchy of larger and larger clusters until finally a single cluster contains all the samples (Gauch 1982). Cluster analysis will be performed in SAS and Euclidean distance will be used as the Cluster Distance Measure and Ward's method will be used in the Group Linkage Method. The groupings generated in cluster analysis with be overlain on the site ordination to determine final groupings.

Ordination

Ordination will be used to find relationships among species, communities and environmental variables. Ordination reduces the dimensionality of the data to 1-3 most important axes to which environmental gradients can be assigned. The ordination technique used in the analysis of the herbicide data will be DECORANA (Detrended Correspondence Analysis). Decorana detrends and rescales the axes thereby reducing the arching and compression of axes problems associated with other ordination techniques (Reciprocal averaging, Principle Components Analysis). Once final groupings are determined on the ordination specific environmental variables can be assigned to the variation outlined on the ordination axes. For the herbicide data there likely will be a strong difference between treated and untreated transects along the first axes.

Measures of Species Diversity

It is recommended that an index of species diversity be used to determine if there is a difference between the plant species diversity of the two treatments over time. Peet (1974) provides a good review of the various species diversity indices available. These indices can basically be split into 3 categories 1. Species richness 2. Species evenness and 3. Heterogeneity indices.

Species richness is an indicator of the relative wealth of species in a community (Peet 1974). The problem with measures of species richness is that they are dependent on sample sizes. The larger the sample size the greater the expected number of species.

Species evenness refers to the relative abundance of individuals over the species list. A community with uniform abundance of the species would have higher diversity. It is necessary to know the number of species in the underlying sample universe or

community in order to use species evenness indices. This is often impossible to determine for most ecological applications (Peet 1974).

Heterogeneity indices combine both the evenness and richness components. There are two distinct types of heterogeneity indices. Type I indices are those that are most sensitive to changes in the rarest species and type II indices are those that are most sensitive to changes in the importance of the most abundant species (Peet 1974). Peet also recommends that heterogeneity indices be used when the underlying species-abundance relation and the number of species in the universe are unknown.

For this study it is recommended that a combination of species richness (total number of species), mean number of species/plot, and type I and II heterogeneity indices, be used to assess the plant species diversity across the various treatments over time. A combination of a number of these indices will allow one to determined the underlying species structure of the various treatments. For example if the untreated sites had a high species number and a high value for a type I index (rare species) with a dramatic decline in value of the type II index (common species) compared to the treated plots, would indicate a number of plant species are being affected by the herbicide treatment. An example of type I and II heterogeneity indices would be Hill's N1 and N2 indices.

5.0 Monitor Procedure

5.1 Timing and Frequency of Monitoring

Year	Crop tree assessment	Vegetation change assessment
0	Yes	Yes
1	Yes	Yes
2	No	Yes
3	Yes	Yes
4	No	Yes
5	Yes	Yes
10	Yes*	Maybe**

* Proponents may incorporate their own growth and yield program into this measurement.

** If there is no change in the vegetation between year 4 and 5, year 10 vegetation change assessment is not required.

Two photos should also be taken at each plot site at the time of measurement. The photos will be taken at photo points established in the crop tree and vegetation plots. Remeasurements should be done at the same time of the year that the initial measurements were taken.

Appendix B: Sample analysis of data for Boreal Mixedwoods d ecosites.