SECTION 7: Site Adjustment Treatments

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7 SITE ADJUSTMENT TREATMENTS

Site adjustment treatments – commonly referred to as site preparation – are generally used to ameliorate site conditions that limit conifer seedling establishment. Treatments accomplish this through changing or ameliorating soil and/or site conditions (van der Gonna 1989).

Örlander *et al*. (1990) describe site preparation as being carried out to create a favorable environment for establishment and growth of seeds or seedlings, or to facilitate silvicultural activity. Boateng *et al.*(2006) identify common limitations to coniferous establishment – driven by young soils and harsh climatic conditions – as low soil and air temperatures, excess soil moisture, poor soil aeration, reduced light availability and (or) mechanical damage by surrounding vegetation.

Site adjustment treatments are most likely to succeed when both the direct limitation(s) to seedling growth and underlying causal factors are addressed. Limitations to establishment and growth are more fully discussed in Sections 4 and 10; the following synopsis is a preamble to discussing site adjustment treatments:

- Soil temperature too cold or staying cold in spring;
    - The optimal soil temperature range for white spruce root growth is 15 to 25°C (Landhäusser *et al* 2001).
    - Minimal white spruce root growth occurs at 5°C (Landhäusser *ibid*, Örlander *ibid*).
    - No aspen root growth occurs at 5°C, while large amounts of aspen root growth occur at 25°C (Landhäusser *ibid*).
- Soil moisture too high – either periodically (flooding) or continuously;
    - Lees (1963) inferred that white spruce seedlings could survive approximately 10 days of root inundation before they would drown.
    - Soils continuously at or near field capacity impair white spruce seedling growth and survival through reduced uptake of nutrients due to lack of oxygenation (Kraskowski and Elder 2000).
- Soil moisture too low – either periodically (drought) or continuously;
    - White spruce is able to avoid drought by ceasing to transpire (i.e. closing its stomata), but it does so at the cost of foregone growth opportunity (Örlander *ibid*).
    - Anecdotal (Formaniuk *pers comm*) observation suggests that deciduous seedlings (1 year old) can tolerate a severe periodic drought better than conifer seedlings (1year old) as they simply shed their leaves to minimize transpiration moisture losses and then re-flush the following year, whereas conifer seedlings will lose moisture through the needle cuticle even if stomata are closed.
    - Sites with continuously low soil moisture seldom grow white spruce or aspen due to recurring drought reducing the long-term viability of these species (see Appendix 2 for Edatopes).

- Soil nutrients too low;
    - Low soil nutrients result in trees having insufficient phosphorus and nitrogen to provide energy as well as insufficient branched chain amino acid synthesis for growth (see Appendix 2 for Edatopes). Note that nitrogen mineralization and therefore its availability for tree growth is inhibited by dry conditions (Evans *et al.* 1998).
- Soil nutrients high resulting in high levels of vegetative competition;
    - High nutrient levels may permit fast growing species to effectively overwhelm the site prior to white spruce (and in some cases aspen) being able to establish.
- Low lying areas where late spring/early summer frosts accumulate and damage succulent juvenile tissue.
    - White spruce is particularly susceptible to spring frost damage. This form of injury may be hard to detect but it can pose substantial challenge to white spruce growth. (Lieffers, *pers comm*)

      Stathers (1989) describes two causes of spring frost. Radiation frost occurs on calm, clear nights when the ground surface cools through radiation of the heat toward the atmosphere. Advection frost occurs when air cooled elsewhere moves onto the site. In the case of advection, the root cause of frost is likely radiative cooling elsewhere. While most site factors contributing to increased spring frost injury risk are of a scale too large to be affected by site adjustment treatments, the risk of stagnant air is not. Advective frost conditions can be exacerbated by cold air being trapped by breaks in airflow. Such breaks may be caused by vegetation or by topography or other physical barriers. Site adjustment treatments that enhance airflow by breaking up impediments may reduce risk of advective frost accumulation. Conversely, site adjustment using linear treatments that block airflow near the base of slopes may contribute to increased risk of spring frost.

      Particular attention should be given to late spring frost when in a high risk area. High risk areas, at a meso-scale, include: the base of steep north facing slopes, slope bases ending against tall, dense forest (which will stop air flow), and bowl-shaped topographic features. High risk areas at a macro-scale can be found on the Environment Canada Risk of Late Spring Frost Map – found at: http://www.nrcan.gc.ca/earth-sciences/geography/atlas-canada

- Exposed areas where seedlings are exposed to the risk of winter injury (see Section 9);
    - Winter desiccation is caused by seedling tops initiating transpiration due to high air temperatures whilst roots are still frozen due to low soil temperatures. Potential for winter desiccation is both site and region based. That is, sites with high wind exposure and southerly or westerly aspects are more prone to desiccation if they occur in a region where sustained above-freezing winter temperatures may occur.
    - Dry winter air, particularly under windy conditions, can induce desiccation due to a high moisture gradient across the cutin on seedling needles. The interior of the seedling is

substantially more humid than the outside and cutin on the needles of young seedlings may not be sufficiently robust to prevent moisture moving across the gradient toward the drier outside air.

- Site adjustments to enhance aspen regeneration. There is an emerging interest in using site preparation to enhance deciduous (particularly aspen) regeneration (Landhäusser *et al* 2006, Fraser *et al* 2003, Sheppard 2001). Evidence to date suggests variability in response to treatment with some types of mechanical site preparation increasing number of aspen suckers, others having relatively little effect on aspen density, and others reducing the number of suckers. Mechanical site preparation can also affect aspen health through wounding which creates entry ports for pathogens (Pankuch *et al.* 2003).
- Compaction or massing of fine textured soils due to harvesting activity during wet, unfrozen conditions resulting in reduced aspen suckering.
- Inadequate aspen suckering due to a combination of lack of thrift in the parent stand (see Section 4) and low soil temperatures due to slash or organic cover insulating aspen roots in the upper mineral soil horizon.
- Competing vegetation may limit tree establishment and growth (Sutton 1993, Navratil 1996). Vegetative competition is discussed at more length in Section 4, however, site adjustment treatments may exert some control on competing vegetation or they may aggravate competition by stimulating emergence of competition.

If none of the foregoing impediments are encountered, or if one or two are encountered at low severity, planting without site adjustment may be considered. Planting without site adjustment can substantially reduce silvicultural costs. Not employing site adjustment may also reduce emergence of seedbanking competitive species, such as raspberry and beaked hazel. While planting without site adjustment will not reduce reedgrass populations, it may result in less reedgrass density than some forms of site adjustment treatment which stimulate reedgrass rhizomes to emerge.

Planting without site preparation requires more attention to propagule selection as depth of forest floor / duff becomes a primary factor in selecting root plug characteristics (see Section 8 - Propagule Deployment). Similarly, without site adjustment treatment to reduce initial competition burden, monitoring of competition and early deployment of vegetation management treatments may be necessary (see Sections 5.9 and 5.10). On mesic sites with fine textured soils (sandy clay loam or finer) planting without site adjustment may result in micro-topographic flooding, particularly at spring thaw. Small scale bowl or “pot and kettle” topography is particularly susceptible to this phenomenon. If such topography is identified, microsite selection criteria should include planters identifying areas of high flooding risk and avoiding them, either by planting on a raised microsite within the high-risk area or by not planting in such areas.

While there is a wealth of literature on outcomes of replicated research trials on success of site adjustment treatments, the literature often does not describe the limitations to growth or the site factors adjusted thereby limiting the resolution with which inferences can be drawn and the practitioner’s ability to prescribe site adjustment treatments. The following text offers guidance in identifying limitations to growth based on site factors, and then in selecting site adjustment treatments to overcome the limitations identified.

Frequently, site preparation treatments used to ameliorate a single limiting factor exacerbate another limiting factor. This is attributable to the potentially dramatic impact of site adjustment factors on soil. For example, mixing treatments designed to provide a seedbed and nutrient enhancement may stimulate seedbanking species (like raspberry), causing increased competition.

In addition, in mixedwood silviculture, site adjustment treatments must be considered in light of unintended consequences to coniferous and deciduous crops. Conifer-focused silvicultural practices often reduce or jeopardize deciduous crop establishment. **This is particularly important given the Leave For Natural (LFN) propagule model presently used for most deciduous crop establishment: that is, silvicultural treatments can subtract from deciduous crop success more readily than they can contribute to it.**

Site adjustment treatments can reduce deciduous crop (particularly aspen) success by a number of means:

- The desired outcome of the site adjustment treatment renders the site less suitable to aspen.
- The treatment directly impacts aspen reproductive potential by destroying root mass with an attendant reduction in suckering potential.
- The treatment results in the site becoming more favorable to a species that competes strongly with aspen, for example reedgrass.
- Contact between the site preparation equipment and aspen roots results in breakage and wounding creating entry ports for root diseases that compromise aspen viability.

To complicate matters further, interactions between site adjustment treatments are frequently equivocal as treatments may adversely affect the distribution or vigor of aspen reproduction while stimulating suckering and thereby increasing aspen density.

Site adjustment treatments are described without relation to conifer propagule type and size; however, these components of conifer regeneration planning are closely linked. Silviculturists frequently use larger stock sizes or season of planting to reduce site adjustment intensity (Section 8).

Site adjustment treatments may also limit the ability to create an intimate mixedwood structure. For example, scalping treatment with a blade, if done deep enough to disturb aspen root structure, will remove aspen from all treated areas. Conversely, linear mixing treatment (e.g. disk trenching, ripping) often stimulates suckering resulting in very uniform aspen emergence across the treated area.

Figure 7.1 is a dendrogram that links limitations to tree growth to site factors. Site factors are those conditions amenable to adjustment by site adjustment treatments. The dendrogram is intended to help the practitioner link site adjustment treatments to “basic” causes of limited reforestation success.

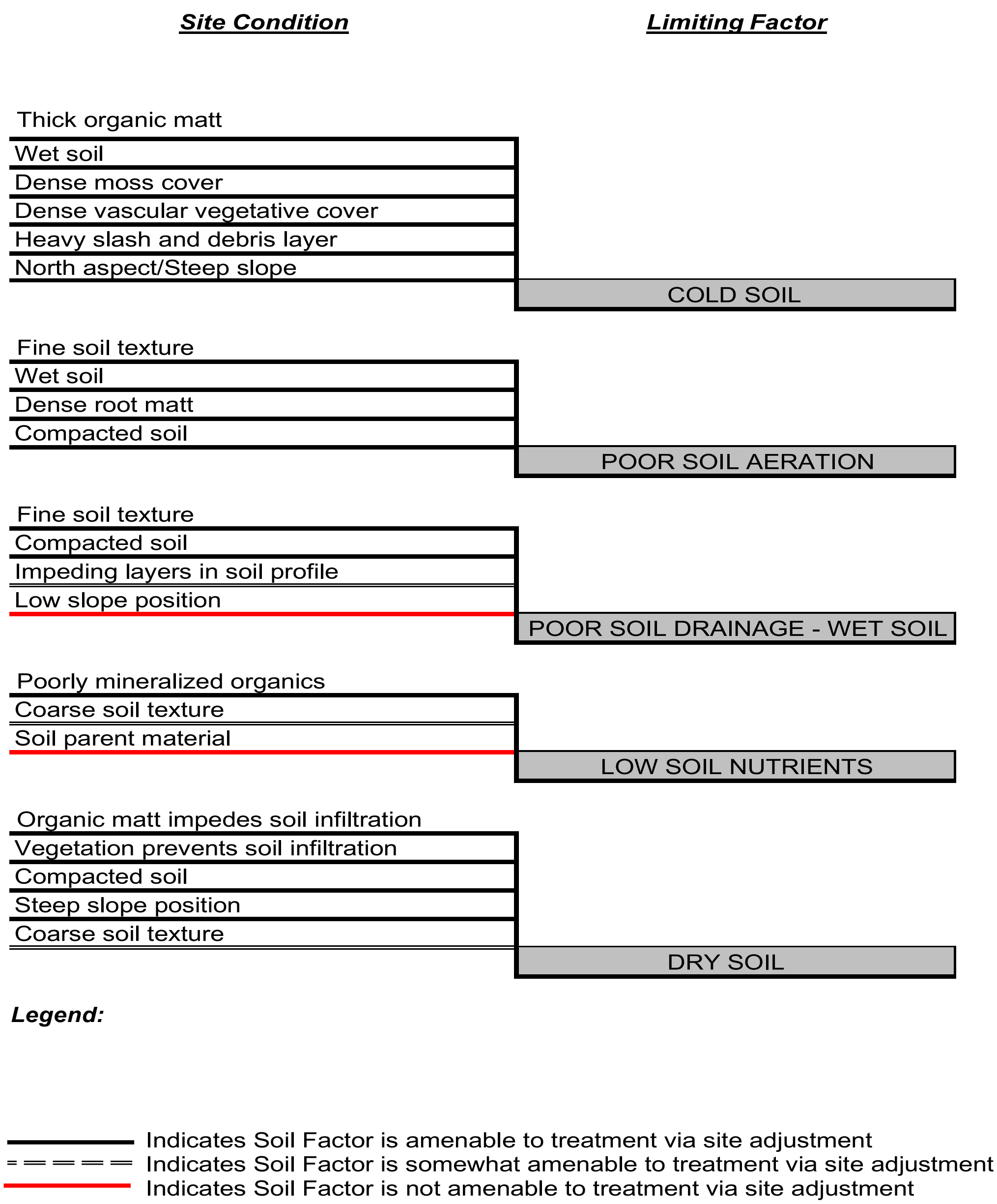

Figure 7. 1. Dendrogram relating site factors to limitations to growth.

7.1 SITE ADJUSTMENT EFFECTS

This section will classify site adjustment treatments into categories by their effect. Seven treatment categories are used. Methods and equipment not included in this guide could be deployed to achieve similar adjustment effects. Specific guidance on use of equipment is beyond the scope of this guide.

Debris management: a treatment to remove, re-align or consolidate logging debris (slash). Debris management treatments do not focus on soil effects, their purpose is to remove or re-align slash to provide planting access for coniferous tree planting and/or to remove soil surface insulation to improve the amount and uniformity of aspen sucker emergence.

Scalping; removal of duff, forest floor and possibly some mineral soil without mixing. Depth of treatment is critical; a “true” scalp will only remove the forest floor and possibly humic organic material from the mineral soil. Care should be taken when using scalping treatments to avoid treating too deep; scalping, particularly with a blade, is capable of removing the humic organic layer or the “A” soil horizon reducing soil nutrient levels and removing aspen roots. Scalping can glaze fine textured (silty clay loam or finer) soils, especially if they are wet at time of treatment, resulting in loss of soil structure.

Scalp-mix: removal of duff with some mixing of duff and mineral horizon below. Similar care to that taken with scalping should be used with this treatment. Scalp-mix treatments (heavy drags) are commonly used to re-align slash, create a mixed mineral–organic seedbed (on thin soils), and locate pine cones near the soil surface to stimulate opening. Scalp-mix treatments have also been tried for debris management in areas where in-block chipping has occurred.

Mix-passive: mixing of organic (duff) and mineral soil accomplished by forward motion of the implement. Mixing treatments are used to blend organic and mineral soil components to enhance nutrient mineralization (and thus availability to crop trees) and to increase soil permeability to rainfall. Note that mixing treatments are likely to stimulate increases in the population of root reproducing species.

Mix-active: mixing of organic and mineral soil accomplished by powered movement of the implement. Active mixing provides the benefits of passive mixing with some vegetation control. With sufficient speed and intensity (depth/frequency of cutting implements) active mixing can effectively macerate the roots of woody sprouting and/or suckering species (like aspen) thereby reducing their propagule potential. Active mixing does not effectively control herbaceous species that reproduce from root structures (like reedgrass). Differences in response of root reproducing species to active mixing is primarily a function of the ability of active mixing equipment to macerate roots into sufficiently fine pieces to eliminate connections between reproductive structures and carbohydrate reserves necessary for initial growth.

Mix-raised: mixing of organic and mineral soil accompanied by raising mineral soil and mixed material into a berm or spoil-bank from the furrow created by the implement. Mix-raised treatments are a compromise between operability, site coverage and effectiveness. They do not provide the level of competition control provided by raised and inverted treatments but do provide some measure of competition control while providing excellent coverage of the site and offering an array of planting microsites. Any control of reedgrass mix-raised treatments provide for a few months after treatment is likely offset by stimulation of reedgrass vegetative reproduction.

Raised and inverted: a raised microsite created by exposing mineral soil through inverting upper soil horizons – resulting in a sandwich of two thicknesses of organic profile material between two layers of upper soil profile mineral layers. Raised and inverted site preparation ranges from fairly small microsites created with linear "mounders" through thick mineral "caps" on large mounds made with specialized excavators.

Table 7.1 associates the microsite effects with specific site preparation implements. Table 7.3 indicates the relationships between generic site adjustment effects and amelioration of limiting factors. Table 7.4 shows effects on seed-banking and root reproducing competitive species.

Table 7.1. Relationship of site preparation implements to site adjustment effects.

Site Adjustment Implements	Treatment Effects							
	Debris management	Scalp	Scalp - Mix	Mix-passive	Mix-active	Mixed - raised	Raised & inverted	Chemical site preparation
Drag	X	X						
Heavy Drag	X	X	X					
Blade	X	X						
Toothed Blade	X	X	X					
Shear Blade	X	X						
Brush Rake	X	X	X					
Excavator Pile	X							
Excavator Screef		X	X					
Disk Trencher	X		X	X		X		
Power Disk Trencher	X		X	X	X	X		
Bedding Plow							X	
Meri Crusher					X			
Ripper Plough	X			X		X		
Bracke							X	
Donaren							X	
Terra Mounder							X	
Excavator Mound							X	
VH Mulcher					X			
Glyphosate								X
Imazapyr								X

Table 7.2. Applicability of treatment effects in managing limiting factors.

Site Conditions	Treatment Effects							
	Debris management	Scalp	Scalp - Mix	Mix-passive	Mix-active	Mixed - raised	Raised & inverted	Chemical site preparation
Coarse soil			*X*	*X*	*XX*	*X*		
Competition							*X*	*X*
Dense roots		*X*	*X*	*X*	*XX*	*X*	*X*	
Fine soil texture						*X*	*XX*	
Heavy slash	*XX*	*X*	*X*	*X*				
Impeding layers						*X*	*X*	
Moss cover	*X*	*XX*	*X*					
Poor mineralization				*X*	*XX*	*X*	*X*	
Rapid drainage		*X*						
Soil compaction						*X*	*X*	
Thick organic matt		*XX*	*X*			*X*	*X*	
Wet soil						*X*	*XX*	

Table 7.3. Impact of site adjustment treatment effects on competing vegetation..

Competing Species	Treatment Effects							
	Debris management	Scalp	Scalp - Mix	Mix - passive	Mix - active	Mixed - raised	Raised & inverted	Chemical site preparation
Alder	0	+	+	+	+	-	-	-
Aspen - suckers	+	-	+	++	-	+	-	- -
Aspen - seed	0	+	+	+	+	0	0	0
Beaked hazel	+	+	+	+	+	-	-	0
Fireweed	+	+	+	+	-	-	-	0
Raspberry	+	+	+	+	+	0	-	0
Reedgrass	0	++	++	++	+	-	- -	- -

Legend: - means the treatment effect reduces density and/or growth of the plant species.
0 means the treatment effect has minimal impact on density and/or growth of the plant species.
+ means the treatment effect increase density and/or growth of the plant species.

7.2 DEBRIS MANAGEMENT AND SCALPING TREATMENTS

Debris management treatments do not impact soil – they focus entirely on relocation and management of logging slash and other debris. Scalping removes live vegetation and the organic matt to the mineral soil surface with minimal disruption of the mineral soil profile. Scalping treatments are used to make planting opportunities more uniform, to remove impediments to planting, or to assist in pine establishment by dispersing cones and aid cone opening. In some cases, scalping can be used prior to artificial seeding, or in anticipation of natural ingress, to improve germination by exposing mineral soil and/or humus. However, scalping has little effect on other factors that constrain conifer establishment or growth. Conversely, scalping can significantly impact deciduous regeneration potential – either by stimulating sucker emergence if treatment is shallow, or removing sucker buds with the aspen root if deep, thereby preventing aspen emergence in the treated area.

Generally, implements that shear vegetation or soil surface material are used for scalping (Figures 7.2, 7.3, and 7.4). The simplest form of scalping is boot screefing where the planter kicks away vegetation and organic debris to create a more uniform planting spot. From screefing, scalping treatments progress upwards in intensity, from hand-scalping with shovels through the use of blades, rakes and shallow ploughs on heavy equipment.

Scalping may control competitive species originating from a seedbank by relocating the seedbank away from the intended planting site. However, scalping may be used prior to implementing a mounding treatment. In this context, scalping is used to clear the reforestation area of logging slash and other debris that would interfere with effective site adjustment.

Figure 7.2. Dozer with a straight blade scalping.

Figure 7.3. Area "scalped" using a dozer with a straight blade.

Figure 7.4. Results of a shear blade treatment made to remove debris.

7.3 SCAP-MIX AND MIXING TREATMENTS

Mixing treatments use mechanical action to blend organic material and mineral soil. The mechanical action used for mixing may result from the shape of the implement (e.g. drag teeth, shark-fin barrels, or ripper plough) or from power assist (e.g. power-disk trencher, A2 Forester™, or Meri-crusher™). Mixing may be done on a small scale with hand tools or small power assist implements but is best accomplished with larger implements using a crawler tractor or large skidder/forwarder as a prime mover.

Mixing depends on two factors:

1. A means of lifting and stirring soil material
2. Operation of the implement at the mineral soil–organic material interface.

These factors mean mixing requires an implement of sufficient size to reach the mineral soil surface with sufficient strength for use in demanding conditions.

Mixing on sites with thin organic layers is often used to ameliorate lack of nutrients by increasing mineral soil–organic material interface thereby increasing mineralization of organic nutrients. Mixing to enhance mineralization need not be deep; therefore, these treatments are often implemented using drag chains or other “light” mixing treatments. Drag chains are heavy chains with large spikes welded to a portion of the chain links (Figures 7.5 and 7.6). Mixing effectiveness of drag chains depends on the weight of the chains and performance of the prime mover, as operating speed is a factor in drag chain effectiveness. Dragging works best at speeds between 3 and 5 kilometers per hour.

Mixing treatments are sometimes employed to spread and incorporate residues left behind following in-block chipping for pulp production.

A variety of microsites for planting can be created with mixing treatments (Figure 7.7). Depending on site conditions, planting locations can be selected to maximize the effectiveness of the treatment.

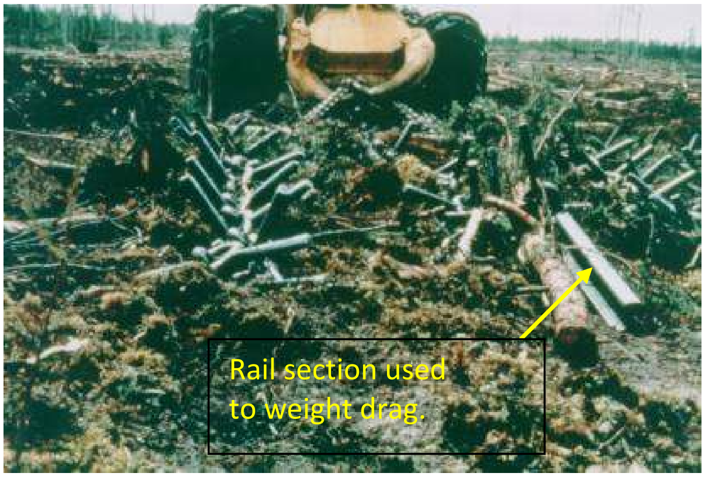

Figure 7.5. Anchor chain ("light") drag.

Figure 7.6. Shark fin barrel ("heavy") drag.

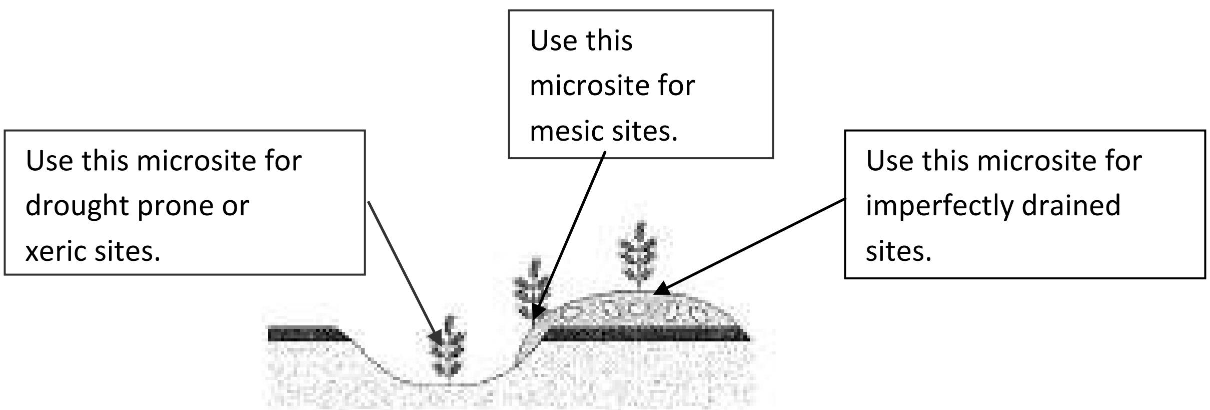

Figure 7.7. Profile of a "light" mixing treatment showing potential planting locations.

Drag effectiveness can be improved by integrating a second implement to the drag. Ripper drags are the most common example of this approach – the ripper is used to scuff up mineral soil and organics that are then mixed by the drag chains that follow each ripper.

Powered rotating site preparation equipment (e.g. power disk trencher, Meri-crusher, VH mulcher (Figures 7.8-7.10)) is most frequently used to implement mixing site adjustment prescriptions, i.e. active mixing. Active mixing equipment is most commonly used in summer and carried on skidders or forwarders, whereas mixing treatments made in winter are most commonly applied using ripper ploughs on large crawler tractors. Equipment where the scarifier rotates on a horizontal axis and follows the prime mover is most common; these implements exhibit a broad range of treatment intensities as assessed by depth of treatment and rapidity of mixing. The Meri-crusher is a small mixer frequently mounted on tracked skid-steer equipment and used to create planting strips or spots in mature aspen stands as a prelude to underplanting (Figure 7.8). The powered disk trencher is the opposite extreme from the Meri-crusher; sinking large, angled disks fairly deep into the soil, this equipment can be used to create slightly raised, well-mixed planting spots that provide enhanced soil nutrient availability with some measure of soil moisture management (Figure 7.9). This sort of regime will frequently suffice in mesic to sub-hygric moisture regimes.

Moderate mixing treatments are often highly effective in stimulating aspen suckering resulting in very uniform aspen emergence while reducing white spruce–aspen competition to levels that do not compromise spruce survival. Observation of operational linear mixing treatments suggests this form of site adjustment (on mesic to sub-hygric, moderate to rich nutrient regime sites) followed by white spruce planting is highly successful in a mixedwood establishment regime.

Figure 7.8. Meri-crusher mixing sod and mineral soil in "old field" reforestation.

Figure7. 9. Bräcke powered-disk trencher.

Figure 7.10. VH mulcher creates individual mixed planting spots.

7.4 MIXED-RAISED AND RAISE AND INVERTED TREATMENTS

Rippers (Figure 7.11) can be used as a mixing implement without the addition of drags. Ripper ploughs are commonly used to provide mixed-raised microsites in frozen soil, thereby allowing silviculture treatment during seasons when sites are accessible. When using implements like rippers which have the potential for more intense site disturbance, care should be taken to ensure the implement does not get used so deep as to result in lower soil horizons with fewer nutrients being incorporated into the mix. Figures 7.12 and 7.13 illustrate well-mixed planting sites with optimal blending of mineral and organic materials.

Elevated microsite site adjustment is a very common site preparation prescription in the Boreal and sub-Boreal forest. In large part this is due to the ability of elevated microsite treatments to address several constraints simultaneously. First of all, elevated microsites are very effective in reducing the risk of flooding or alleviating generally wet soil. The prevalence of wet sites in the Boreal biome accounts for much of the popularity of raised microsite site adjustment treatments.

Figure 7.11. Ripper plough used to make mixed - raised treatments in winter.

Secondly, a properly formed elevated microsite will relocate organic and most mineralized nutrients in the immediate area to favor the planted seedling over competing vegetation and will increase the temperature of the site to enhance seedling growth. Mounds are made by dragging a shaped implement into the organic mat and downward into mineral soil. Once a depth approximately equal to the height of the desired mound is reached, the implement is pulled inward to lift and flip a layer of soil and organics onto the undisturbed soil. This results in a profile similar to that shown in Figure 7.14. Seedlings are planted across the profile depending on the combination of site conditions being addressed. On dry sites, seedlings should be planted below the “hinge” (point 2 in the schematic). On occasionally flooded sites, seedlings should be planted just above the hinge (point 3 in the schematic). On very wet or frequently flooded sites, seedlings should be planted near the top of the mound (point 4 in the schematic). Note that planting near the top of the mound can result in drought stress to seedlings if the site is occasionally dry. Further, seedlings planted near the top of the mound are susceptible to temporary nutrient deficiency when the organics forming the core of the mound begin to decompose and thereby tie up soil nitrogen (point 5 in the schematic).

Figure 7.12. Well mixed planting sites shortly after treatment.

Figure 7.13. Raised microsites made with a ripper plough.

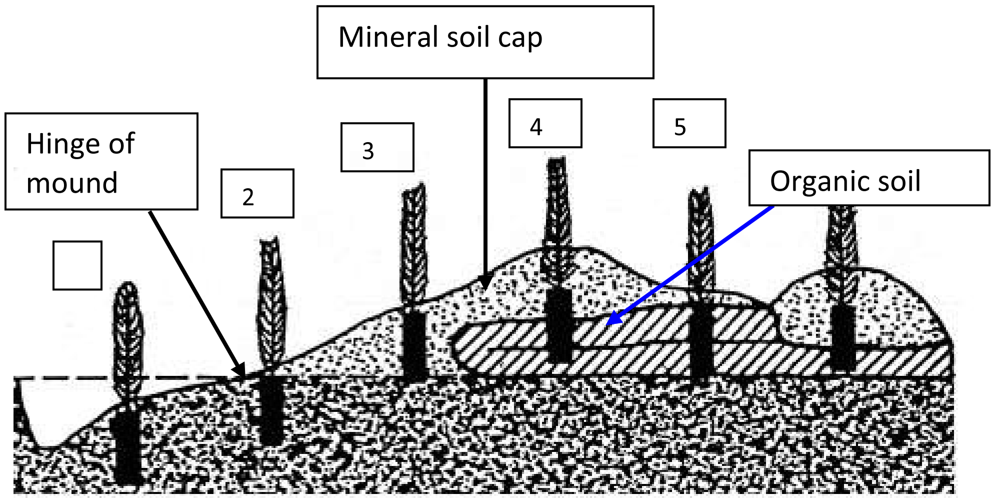

Figure 14. Structure of a "mound" showing choices of planting microsites. (*after Örlander et al, 1990.)*

Elevated microsites can be created using linear implements, in effect creating a continuous raised bed, such as bedding ploughs, rippers, and even front mounted ploughs (Figures 7.15 and 7.16). There are several linear mounders developed to automate or semi-automate the process of creating raised beds. These range from the Bräcke scarifier through the Bräcke-Donaren mounder, the Dual-Path mounder, and the BC Ministry of Forests (RivTow) mounder. The Bräcke-Donaren mounder is currently the most popular "line mounder" in common use (Figure 7.16). Line mounders can create shallow to medium height mounds. As intensity of treatment is increased, number of raised microsites per unit area is decreased as larger raised microsites require more area.

Large, tracked excavators are commonly equipped with specialized buckets designed to create elevated microsites (Figures 7.17 and 7.18). While slow and therefore expensive, excavators are the most versatile of site adjustment tools because, with a skilled operator, every microsite can be tailored exactly to existing soil conditions at the treatment spot.

The wide range of elevated microsite-producing equipment means this prescription can be optimized for operational constraints such as frozen soil, difficult winter access, patchy wetness, and water seeps on hillsides that would be susceptible to erosion if treated with linear site preparation equipment.

Figure 7.15. Bedding plough making a "continuous mound" or raised bed.

Figure 7.16. Bräcke - Donaren line mounder.

Figure 7.17. Excavator mounding.

Figure 7.18. Specialized mounding "bucket" for excavator mounder.

7.5 LONGER TERM OUTCOMES OF INTEGRATED SITE ADJUSTMENT AND STAND TENDING TREATMENTS

Boateng et *al* (2006) reported longer term outcomes of six site adjustment treatments employed alone and in concert with "early" chemical release treatments. They evaluated four intensities (thickness of mineral cap) of raised inverted treatments compared to patch and blade scarification. Chemical release treatment was spot application of glyphosate in a 1-m radius around planted seedlings one year after planting. Planting locations were either on the mineral soil cap or the hinge of raised inverted treatment spots or on the bare mineral soil generated by blade or patch treatment. While early results suggested there were differences in reforestation performance associated with differing mineral cap thicknesses, 20-year post-treatment results found all raised inverted site adjustment treatments gave similar outcomes which were superior in terms of both growth and performance to blade or patch treatments. Larger seedlings were planted without site adjustment to assess whether increased stock size could be used to replace site adjustment. After 20 years, treatment outcome trended toward one of two outcomes: with the combination of raised, inverted site adjustment and early conifer release giving approximately double the basal area of either untreated controls or blade scarification. Clearly, in an environment where cold, wet soil and reedgrass act together to limit spruce survival and growth silviculture strategies that address all limiting factors result in substantial improvements in survival and growth.

7.6 CHEMICAL (HERBICIDE) SITE PREPARATION

Herbicide site preparation is a special case of scalping in which chemical herbicide is applied to a cutover area prior to initiating conifer regeneration treatments. Like other scalping treatments, herbicide site preparation does not influence edaphic limitations to seedling establishment – that is, it does not change soil moisture or nutrient regimes. Herbicide treatments, regardless of timing, provide only competition control. At present, glyphosate and imazapyr are the only herbicides available for forest management in Alberta that are suited to site preparation use.

Glyphosate controls a wide array of plant species that compete with coniferous crop seedlings, including reed grass (*Calamagrostis canadensis*), raspberry (*Rubus ideaus*), fireweed (*Epilobium angustifolium*), alder (*Alnus* spp.), and willow (*Salix* spp.). It also controls deciduous tree species, thus making routine use of glyphosate in mixedwood silviculture challenging. This challenge is exacerbated by the fact that herbicide site preparation is most effectively applied as a broadcast treatment; when applied as a spot or small patch spray, glyphosate does not give lasting control of bluejoint reedgrass. Glyphosate is most effective in controlling reedgrass when broadcast applied at 3.2 kg (ae)/ha with an organosilicate surfactant system. Finally, best control of reedgrass is gained when glyphosate is applied late in the growing season. All the foregoing factors combine to make glyphosate less than ideal as a mixedwood management tool due to the fact that rate and timing will kill deciduous regeneration present at treatment.

Conversely, glyphosate treatments applied within two or three years of harvest generally show better post-treatment recovery of deciduous trees than do openings treated later. Deciduous recovery often occurs in the form of balsam poplar, with densities of 1,000 to 2,000 stems/ha (Pitt *et al* 2004; Greenway *unpublished*).

Imazapyr, a herbicide widely used for forestry throughout most of the developed world, received registration for site preparation on Boreal sites in Canada in January 2007. Unlike glyphosate, imazapyr is not approved for broadcast application. However, it provides durable control of reedgrass with spot or small patch application. While imazapyr controls deciduous suckers or saplings that have been oversprayed, there is no evidence of outward translocation from treated aspen to adjacent untreated aspen in approximately 15 research trials conducted across Canada. Imazapyr is registered for ground application only with a maximum of ½ (50%) of the opening area being eligible for treatment using spots, patches or strips. Imazapyr site preparation may be a means of establishing intimate mixedwood stands on sites with bluejoint reedgrass competition.

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