Experimental comparisons of site preparation and planting treatments to reclaim linear corridors in the boreal forest

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Executive summary

Linear corridors created for exploration and access during industrial development leave a significant footprint on forested landscapes. In this proposal we will examine the effectiveness of restoration techniques to re-vegetate (trees,shrubs, herbs andbryophytes)linear corridors in the boreal forest in order to remove theirdisturbance footprint and reduce habitat fragmentation.This work is an extension of the DART (Disturbance and Recovery Trajectories) research program. For the next stage of DART we designed a set of experiments to examine the effectiveness of different site preparation treatments, in concert with wood applications, planting and seeding on re-establishing ground vegetation on linear corridors, with a focus on how these treatments affect vegetation recovery and underlying soil processes.By exploring soil-vegetation relationships, this study will reveal the causes for slow vegetation development and also the basic biophysical drivers for faster ecosystem restoration.The work will provide and demonstrate the means for successfully re-establishing forest communities on these corridors, thereby reducing impact on forest biodiversity and meeting current conservation guidelines for caribou population recovery. As an outcome of this work, agencies will be better able to applybest-management practices for decommissioning corridors and have the potential for applying for future conservation offsets.

1. Introduction

Industrial activities such as *in-situ* development, conventional oil and gas activities, exploration for metallic and industrial minerals, geophysical operations, and coal and oil sands exploration have required the establishment of many linear corridorson the boreal landscape (Lee and Boutin, 2006). Depending on construction history and the recurrent reuse of these linesfor industrial or recreational purposes, many of these corridorshave remained unvegetated for extended periods – sometimes for decades with continual or periodic disturbance to soil and vegetation. Corridors fragment the landscape, which is detrimental to wildlife species requiring large contiguous stands (Machtans, 2006). The existing network of linear corridors also facilitate predators and large ungulates access to the same areas where caribou live resulting in increased predation of caribou and thus one potential cause of recent population declines (James and Stuart-Smith, 2000; Schneider *et al*., 2010; Latham *et al*., 2011). Tree felling, seedling planting, and the creation of berms (physical terrain barriers) to restrict motorized off-road traffic on linear disturbances have had varying levels of success, but are unlikely to influence the movement of determined recreationists or predators. There is a need to quickly re-establish natural vegetation similar to that of theboreal mixedwood forest andto restore the normal ecological processes of the boreal landscape.The sooner plant species arere-established, the sooner soil profiles can redevelop and a fully-functional ecosystem can be restored (Bradshaw, 1995). Decommissioning techniques that restrict motorized traffic and encourage rapid re-vegetation and forest floor formation need to be developed.

When constructing corridors in the past, the organic layers were usually bladed off by heavy equipment (Lee and Boutin, 2006) and the surface layers were smoothed, leavinglittlevariation in microtopography. Blading causes large shifts in vegetation type (Bock and Van Rees, 2002; Newmaster*et al.*, 2007) and soil properties.These mechanical operations, together with subsequent motorized traffic, typically result in soil compaction that reducessoil macroporosity and the connectivity of these pores (Arocena, 2007). This detrimental change in the physical soil condition leads to sharp decreasesin aeration and air exchange throughout the soil.For example, some seismic lines are also used for hauling logs by the forest industry which can cause further compaction of soils. The reasons for poor re-vegetation on these sites may relate to poor germination (Johnson *et al.*, 1991) or slow colonization of plant roots into compacted soils. Adjacent vegetation (root systems) also reducesavailable soil moisture on lines causing the sites to be limiting for moisture. Adjacent vegetation also causes these disturbances to be shaded which has an impact on vegetation establishment. Reduced organic matter and lack of microtopography, coupled with compaction,reduces water infiltration into the soil resulting inprecipitation thatsimply runs offthe site making conditions worse for vegetation establishment (Arocena, 2007). Dry and compacted soils significantlyinhibit root penetration (Blouin, 2007)and populations of soil organisms and their resultant biological activity (Cook, 2007). In addition, forest floor and surface humus play critical roles in nutrient cycling, building soil structure and conserving soil moisture(Prescott *et al.*, 1999). However, in upland areas of boreal mixedwood forest where old seismic programs (2D) were conducted, the organic layer werecommonly removed as linear corridors were created. In addition, soil organic matter has not re-accumulated following the recurring disturbancesof these corridors.Finally, many of these sites have been colonized by weed species, inadvertently brought in on machinery. The presence of these weeds further limits the establishment of native tree species.

On wet sites, the freezing-in process and smoothing of the surface removes the hummock-hollow topography typical of most peatlands. The general depression of the peatsurface on corridors may leave most of the wetland sites too wet for establishment of most woody species(Grossnickle, 2000) and some mosses(Granath *et al.*, 2010) due to lack of elevated microsites and a functioning aerated zone.Wet moderate-rich fens may also be rapidly colonized by the flood tolerant and dominant aquatic sedge, *Carexaquatilis*. Thisspecies is described as an ideal pioneer because of its capacity to establish by seed and rhizomes, and its tolerance for a broad range of environmental conditions (Koropchak*et al.*, 2012). Colonization of this species can prevent the establishment of other native and woody vegetation. Recent work by Caners and Lieffers (in preparation) suggests that this sedge-dominated state is similar to early stages of wetland succession (MacDonald, 1987; Kuhry and Turunen, 2006) and may persist for decades following disturbance. All of these factors retard plant growth and tend to keep the corridor in a poorly vegetated state of low diversity.

This research proposal will look at using mechanical site preparation (MSP) techniques and the application of woody materialsto improve the surface microtopography and moisture conditions of soil in order to re-establish boreal forest vegetationon existing linear corridors.Mechanical site preparation has been used successfully to regenerate conifer species (e.g.,Man and Lieffers, 1999; Archibold*et al.,* 2000; Boateng*et al.,* 2006; Gradowski*et al.,* 2008). Only a few studies, however, have examined MSP for promoting growth of boreal hardwoods or other vegetation (Bock and Van Rees, 2002;Newmaster*et al.,* 2007). Moreover, we are unaware of any published research regarding the use ofMSPfor the re-establishment of forested upland or wetland communities on disturbed linear corridors.

2. Objectives

2.1. Management objectives

The goal of a good decommissioning program is to accelerate forest recovery, to restore normal ecosystem processes, and to encourage re-development of locally representative forests on re-vegetating sites. This concept and its application will be especially attractive to industry if the MSP is effective in:(i) enhancing natural re-establishment of common forest vegetation; and (ii) reducing the need for planting.Tree planting, however, might be desirable as it will speed crown closure (see below).A second but more indirect goal is to manage traffic accesson linear disturbances using mound and wood as physical barriers. This is of particular interest because an irregular terraincreated by mounding and wood applications reduces access for off road vehicles, impedes movement of large mammals, improves water infiltration and redistribution in the soil profile, and provides opportunities forcombining mounding with slash applications which may indirectly prove to be even more effective in reducing the unintended use of corridors.Elevated microhabitats in fens are particularly important to the colonization of hummock building species that will reform the hummock-hollow topography.

A study completed in the Little Smoky area suggest that seismic lines take from 20 to 25 years for vegetation to re-establish naturally (Golder Associates Ltd., 2009). Theresulting plant community was composed of deciduous vegetation less than 3 meters in height (Golder Associates Ltd., 2009). Thus, seismic lines are dominated by early successional vegetation for an extended period of time.It was also demonstrated that this early successional vegetation increased ungulate usage due to the cover and browse potential. Establishing conifer species, such as white and black spruce, may limit this browse stage. Mounding site preparation is capable of producing a 2 to 2.5 meter tall white spruce tree in 10 years in Alberta (Tim Vinge – personal observation), thus reducing the browse period in half to 10 years (versus 20 to 25 years).This would be particularly effective if spruce were established at high planting densities.

2.2. Research objectives

Our research objectives are to determine how the application of MSP to highly disturbed linear corridors affects physical soil properties such as macroporosity, hydraulic conductivity (asa proxy for pore connectivity), bulk density,waterholding capacity and water availability for plants as well as vegetation responses such as spontaneous recruitment and floristic composition from natural regeneration, and growth of planted conifer trees.

3. Proposed Research

This proposal builds on work done by the DART project which shows that in many places recovery is substantially delayed (van Rensen *et al.*, in prep).This project will test severalMSP techniques,includingexcavator mounding and sub soiling,in terms of their ability to renew and enhance the physical soil condition and stimulate the development of vegetation. Woody material applicationswill be incorporated into these treatments using a split-plotexperimental design in upland sites and as a standard treatment in wooded moderate-rich fen sites. This project will generate a more complete set of answers than single treatment applications by testing with controls a wide range of treatments for two dominant ecosystems:upland sites in the boreal mixedwood forests under both mesic and xeric soils and in wooded moderate-rich fens.

Methods

A randomized block design will be used consisting of 8blocks (4in each of two locations) per ecosystem type with the three ecosystems targeted beingupland mesic mixedwood forests on fine-textured soils, upland xeric forests on coarse-textured soils, and wooded moderate-rich fens.In each block,several MSP techniques(see below) and a controlwill be applied.Linear corridors will be selected from sites disturbed 5-10 years earlier, sparsely-vegetated, little functioning organic layer, moderately compacted, 5-10 meters in width and of the same orientation and aspect and will have a consistent upland and lowland forest cover type near to each other. For practical considerations, sampling sites will also be as close as possible to all-weather roads and towns/camps for accommodation.

Uniform sections of linear disturbanceswill be divided into three 25 metre long sections (total length of 75 m) for experimental treatments (Figure 1). For the upland mesicmixedwood sites, each 25 metre section will receive one of the following three treatments: 1)excavator mounding with half of the length (12.5 m) randomly assigned toeither a slash rollback (wood application) or not; 2) sub-soiling using a McNabb sub-soiling plowwith again half of the length randomly assigned to either a slash rollback (wood application) or not; or3) a control treatment where no mechanical site preparation is applied, although half of the length will again be randomly assigned to either a slash rollback (wood application) or not (Figure 1a).Wood application represents the nested component of the split plot design. In all three treatments, white spruce seedlings will be planted at an equal stocking rate. For upland xeric forests on coarse-textured soils, three treatments will be applied: 1) surface scarification with slash rollback (wood application) randomly assigned to half of the segment; 2) sub-soiling using a McNabb sub-soiling plow with again half of the length randomly assigned to a slash rollback (wood application); or 3) control with no mechanical treatment, but again half the length randomly assigned to a slash rollback (wood application) (Figure 1b). Black spruce or jack pine seedlings will be planted at an equal stocking rate across all three treatments. Finally, the wooded moderate-rich fens will receive one of the following three treatments (without the split-plot design): 1) excavator mounding; 2) wood application; or 3) a control (Figure 1c). Black spruce seedlings will be plantedonly in mound treatments.

For efficient use of machine time, an excavator utilizing different attachments will be used to achieve the desired effects. A sub-soiling plow is being developed for use on an excavator. An extended strip of mounding will be done on both sides of the treatment area to discourage travel onto the experimental block. For upland sites (mesic and xeric), mechanical site preparation will be completed in the fall of 2014when some frost has entered the ground. Some frost will be desirable in order to minimize additional compaction and to facilitate equipment travel.

In wooded moderate-rich fens, the mounding site preparation (using very large frozen blocks of peat positioned with the growing side up to retain plant reproductive tissues and diaspores) will take place during January-March of 2015 when the peat surface is frozen and can support machinery. A similar experiment was established by Caners and Lieffers (in progress) on rich fens in areas of *in situ* oil sands exploration (OSE),in the Devon Pike area southeast of Conklin in March of 2012. Together with this work on moderate-rich fens,the research outlined in this proposal will provide a comprehensive analysis of treatments to recover fens following linear and *in situ* OSE disturbances in Alberta.

Some preparatory work will need to be carried out in the summer of 2014. For example, the location for the experiment will have to be confirmed through summer visits to candidate sites. Consultation may be required to close access on treated line sections. Pre-treatment data will be collected on vegetation composition and soil properties in late summer of 2014 in all sub-plots, including the controls. At this time, plots will be established in adjacent, undisturbed stands in order to determine the ecosite, vegetation and soil properties under undisturbed conditions (this information will serve as an ecological reference baseline). For upland sites, a soil pit will be dug in the vegetation assessment plot to characterize the soil profile and to also collect soil samples for nutrient analysis. Additionally, physical soil properties, such as macroporosity and unsaturated hydraulic conductivity (as proxies for soil compaction and pore connectivity, respectively), bulk density, soil structure, water holding capacity, water availability for plants, and rooting depth will be assessed on the topsoil and upper subsoil. We will use a soil evaporation method to quantify macroporosity and infer unsaturated hydraulic conductivity and water retention, and tri-dimensional, high definition laser scanning to measure bulk density and soil structure. Soil samples collected during the assessment will be sent to the laboratory for analysis of pH, electrical conductivity (EC), sodium adsorption ratio, carbon, nitrogen, sulphur, phosphorus, potassium, magnesium, and calcium.Soil moisture will be measured at 10 cm depth using gravimetric techniques and at deeper depths in some treatments using instrumentation. Soil measurements will be taken in summer/fallof 2014before treatments are undertaken, in order to examine conditions prior to treatment. For sub-soiling treatments, soil elevation changes will be documented as sub soiling can substantially raise soil elevations.For wooded fens, pH and EC of surface waters, depth to water table, and peat depth will be obtained in the field; water and peat samples will be taken for subsequent analysis of chemical and physical propertiesthat may influence the regeneration of bryophyte and vascular plant species (Locky and Bailey, 2007).

After MSP is completed, vegetation composition will be assessed over the next 3 growing seasons. Five subplots (1 x 1 meter) will be established in the middle and edges of each25 metre plot. Once established these sample locations will be permanently marked and resampled in subsequent years. Species richness and diversity, incursion of exoticweeds and assessment of dominants will be completed. Vegetation data will also be summarized using ordination techniques. In the mounding section, where there is significant topographic variation, smaller vegetation plots will be established to attempt to understand vegetation responses(vascular plants and bryophytes) in relation to microtopography of the mounds.

Soil properties (see above)and their spatial variability will be measured prior to treatment to document the initial soil conditions at the experimental sites, and then again in the 1st, and 3rd summer after treatment with the aim of identifying the effects of mechanical treatments (versus control). This will also be done immediately adjacent to the treatment disturbance and in microsites near the mound holes where soil was apparently not disturbed.We anticipate that these microsites will become less compacted over time because of freeze-thaw cycles.Comparable measurements will be made for organic (i.e., peat) soils in wooded fens.

3.1.1. Planting of White or Black Spruce and Jack Pine

In order to evaluate how well seedlings establish on corridors that have undergone MSP, seedlings of white or black spruce and jack pine(xeric site) will be planted in the spring after treatment. Spruce will be planted because despite its slow juvenile growth, when it does reach crown closure, it shades the understory, retains lower branches and therefore is a strong barrier for line of site and travel on the corridor. A total of 25 seedlings of each species will be planted on each treatment cell; seedlings will be marked with pigtails.Seedling planting location will be on the best available microsite based on silvicultural experience. In mounded areas, seedlings will be planted on the interface position of mounds, always on the scalp side. On sub-soiled areas, seedlings will be planted on the raised portion of ploughed microsites. If sub-soiling is used, it will be important for the frozen lumps to be somewhat levelled, as planting sites may not exist in time for planting the following summer if sites are left too rough. After sub soiling is completed on frozen ground, the excavator will track-pack frozen lumps back into place in order to facilitate planting the following spring. On plowed sites seedlings will be planted on the higher portions of microsites. Seedling mortality, height growth, and root collar diameter will all be measured at the end of the first, second and third seasons.Any browsing of these planted species will also be recorded in order to assess use by wildlife. Microsite position and initial seedling measurements will be recorded at time of planting. Control plots with no mechanical treatmentswill also be planted with the same species. On peatlands, black spruce seedlings will be placed on the highest microsites available in each treatment.

4. Implications of the work.

The goal is to promote, as quickly as possible, the natural forest recovery of these linear corridor features in the boreal landscape.There are several benefits arising from this work:

- New bestmanagement practices for decommissioning lines will be generated from this research.
- Plots will be permanently marked to provide potential for long-term experimental monitoring and demonstration to the public.
- There may also be opportunities to use re-vegetated corridors for demonstrating effective treatments for conservationoffsets.
- Once these line corridors are re-vegetated, this may remove administrative barriers for further exploration or development.
- The public will look favourably on this type of restorative intervention.
- Methods developed will help to remove linear footprints from the boreal landscape and begin to restore the normal ecosystem processesand functions.
- Quick re-establishment of conifers may shade out and suppress browse species that attract ungulates and thus predators.
- Help develop technology transfer, outreach, and demonstration.
- Develop best practices for resolving the recovery of non-regenerating sites.

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Figures

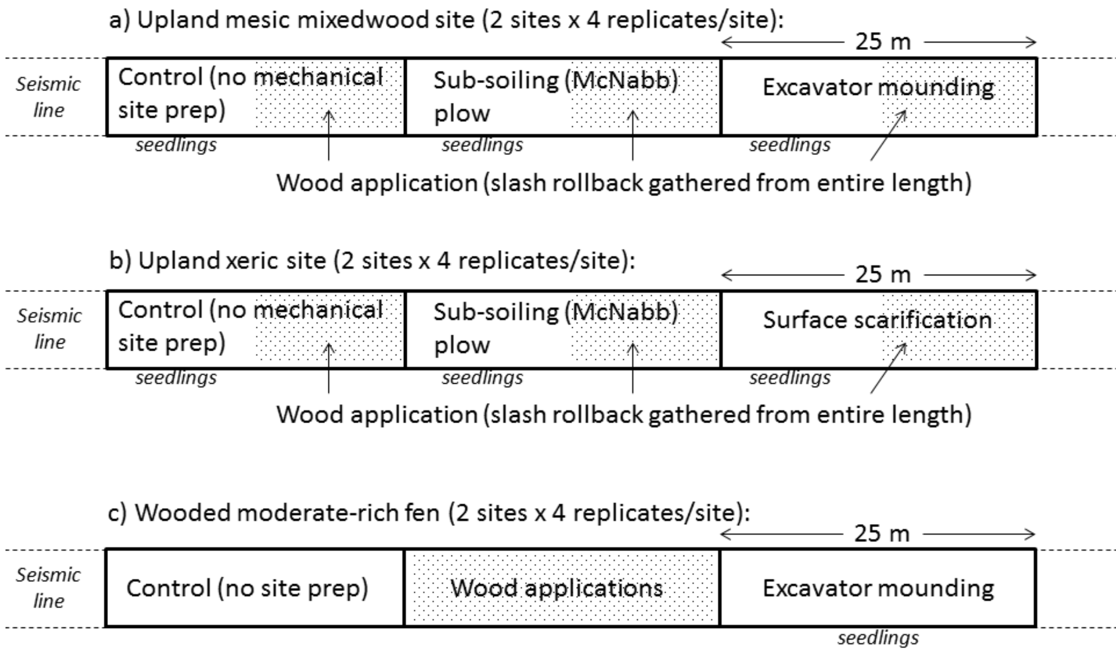

Figure 1. Diagram illustrating experimental treatments of seismic lines for upland mesic sites (a), upland xeric sites (b), and wooded moderate-rich fens (c).

Budget tables

Table 1. University of Alberta research.

	Pre-treatment	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Technician	5,000	0	0	0	0	0
Summer student	2,200	12,000	12,000	12,000	12,000	12,000
Graduate student	0	25,000	25,000	51,000	26,000	26,000
Food & lodging (field)	4,000	10,000	10,000	10,000	10,000	10,000
Truck (field work)	4,000	12,000	12,000	16,000	12,000	12,000
Field/Lab equipment	14,000	2,000	2,000	2,000	2,000	2,000
Supplies & sample analysis	8,500	7,000	7,000	7,000	7,000	7,000
Training, Safety & Communications	3,000	3,000	3,000	3,000	3,000	3,000
Conference, extension	2,500	2,500	2,500	5,000	3,000	5,000
Sub-Total	**43,200**	**73,500**	**73,500**	**106,000**	**75,000**	**77,000**
Overhead 20%	8,640	14,700	14,700	21,200	15,000	15,400
Grand total	**51,840**	**88,200**	**88,200**	**127,200**	**90,000**	**92,400**
					5-year total =	**$537,840**

Table 2. Global Restoration budget.

	Year 1
Reconnaissance for site prep[1]	30,980
Site work[2]	21,780
Site preparation (treatments)[3]	52,525
Total	**105,285**

Notes:

[1]Reconnaissance from Global Restoration:

Discription		
Scouting out 24 apropriate sites, operational planning,	12 days @ 1100.00	15400.00
access management & overseeing line locates		
ATV/Sled	12 days @ 200.00	2400.00
Pickup	12 days @ 225.00	2700.00
Subsistance	16 @ 265.00	4240.00
Travel to and from Ft Mac (twice) Man Hrs	32 Hrs 95.00	3040.00
Travel to and from Ft Mac (twice) Pickup	3200 Km @ 1.00	3200.00
Total		30980.00

[2]Site work from Global Restoration:

Consulting (Site work)	12 days @ 1100	13200.00
Pickup	12 @ 250	3000.00
ATV/Sled	12 @ 200	2400.00
Subsistance	12 @ 265	3180.00
Total		21780.00

[3]Site preparation treatments from Global Restoration

Site	Discription	Trucking HRS	Travel HRS	Machine HRS	Subsitance	Service T	Km Charg
1	Mounding/Wood 4 Reps	6	4	20	2	2.5	
2	Mounding/Wood 4 Reps	6	4	20	2	2.5	
1	Upland mound Rip wood X4	6	4	20	2	2.5	
2	Upland mound Rip wood X4	6	4	20	2	2.5	
1	Sand Rip screef wood X4	6	4	20	2	2.5	
2	Sand Rip screef wood X4	6	4	20	2	2.5	
	Hauling to and from Ft MaC	44	16		1		1600
	Total amount	80	40	120	13	12	
	Charged @	245.00	62.50	190.00	265.00	215.00	1.00
	Total	19600.00	2500.00	22800.00	3445.00	2580.00	1600.00
	Site prep Total						52525.00