Vegetation development on skid trails and burned sites in southeastern British Columbia

by E.T. Oswald and B.N. Brown

Vegetation development, including both planted and natural tree seedlings, was examined over a 5-year period on an area in the ESSFmw subzone of the Nelson Forest Region which was clearcut, skid logged, burned, and planted with 2+0, 313, Engelmann spruce. Study sites included the cutbank, mid-trail, and sidecast portions of the skid trails and the intervening prescribed burned area. Fireweed was the most prominent invading species, and affected tree growth, particularly on the sidecast, by shading and crowding the trees. Black huckleberry, regenerating from root stalks, was common on the burned sites, but had marginal influence on Engelmann spruce development over 5 years. The best tree growth occurred on the burned sites, followed by the sidecast, mid-trail, and cutbank sites. Consideration should be given to omitting the cutbank planting site and moving the mid-trail planting site inward on slopes of 30% or more.

Key words: Engelmann spruce, ESSFmw biogeoclimatic subzone, slash burn, vegetation succession, fireweed

Le développement de la végétation, comprennant à la fois les semis d'arbres plantés et naturels, a été étudié au cours d'une période de cinq ans sur une superficie de la zone de l'épinette d'Engelmann et du sapin subalpin dans la région forestière de Nelson qui avait été coupée, débardée, brûlée et plantée avec de l'épinette d'Engelmann du type 2+0, 313. Les sites étudiés comprennaient des portions de la zone de coupe, du milieu du sentier et des zones buttées des sentiers de débardage ainsi que des superficies brûlées adjacentes. L'épilobe était la plus importante des espèces envahissantes et affectait la croissance des arbres, particulièrement dans les zones buttées où elle ombrageait et recouvrait les arbres. L'airelle noire, se régénérant par des drageons issus de racines superficielles, était commune sur les sites brûlés, mais avait une influence marginale sur le développement de l'épinette d'Engelmann au cours des cinq années de l'étude. La meilleure croissance des arbres a été retrouvée sur les sites brûlés, puis dans les zones buttées, le milieu des sentiers et les zones de coupe. On devrait considérer d'omettre les zones de coupe en tant sites de plantations et de déplacer les sites de plantation sur le milieu des sentiers vers l'intérieur sur des pentes de 30% et plus.

Mots clés: Epinette d'Engelmann, sous-zone biogéoclimatique de l'épinette d'Engelmann et du sapin subalpin, brûlage des débris de coupe, succession de la végétation, épilobe

Introduction

Implementing a silvicultural system on a forested site involves tree harvesting, tree removal, site preparation, and reforestation, with subsequent stand tending as required. Each prescription can be conducted using a variety of techniques, with site characteristics, costs, and equipment availability being key factors in choosing the procedures. Clearcutting, skid harvesting, and prescribed burning are common forestry practices on steep terrain in British Columbia. Clearcutting is the most economical harvesting system and has other attributes pertaining to subsequent reforestation and sanitization. Skid yarding is expedient on level to moderately sloping land, and over 30% of the ground surface has often been utilized for skid trails and landings (Smith and Wass 1976, 1979). The rationale most often given for prescribed burning is based on three primary grounds: (a) to remove slash and/or organic matter to facilitate reforestation (b) to remove slash to reduce subsequent fire hazard and (c) to aid the control of disease infestation. The deleterious aspects of burning include smoke emissions and nutrient losses. This report pertains to a case study of vegetation development, including crop tree growth, following clear cutting, skid harvesting, and prescribed burning of a high elevation forested site in southeastern British Columbia that had a spruce bark beetle infestation.

A retrospective study of reforestation following skid logging on steep terrain in the Nelson Forest Region was conducted by Smith and Wass (1979, 1980). The sample areas included in their study occurred on either coarse-textured acid soils or fine textured alkaline soils, and post-harvest site preparation and planting were not conducted. The analyses of natural regeneration, mostly by Engelmann spruce (*Picea engelmannii* Parry) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), revealed different patterns of species establishment and growth over the sample sites within the Nelson Forest Region.

The present study area occurs in the Glenogle Creek drainage, and consists of a 28.5-ha block in the moist Engelmann spruce – Subalpine fir (ESSFmw) biogeoclimatic subzone (Meidinger and Pojar 1991) northeast of Golden, British Columbia (Fig. 1). The soil has a silty loam texture, a Eutric Brunisol (Cryochrept) (Wittenben and Lacelle 1978) development, and is moderately acidic (pH 4.2–6.1). This site ranges in elevation from about 1580 m to 1825 m with a 40% slope and a northeasterly aspect. The area was logged using conventional ground skidding during the summer of 1983, broadcast burned on August 27, 1985, and planted in September 1985 with 2 + 0, PSB 313, Engelmann spruce seedlings at 1600 trees/ha.

The conventional logging involved the construction of skid trails in a herringbone pattern with a dozer blade; the trails were placed 20–30 m apart and converged obliquely to a main skid trail leading to the landing. The skid trail has a cutbank side that can be over a meter deep in relation to the undisturbed soil surface and a sidecast side which is the depository for material scraped off the trail (Fig. 2). Two compacted tracks are formed by the vehicle treads. Tree seedlings are planted on the lower part of the cutbank slope, on the edge of the sidecast, and sometimes between the compacted tracks (mid-trail), as well as on the burned surface between the skid trails. The objectives of this report are to compare the establishment and growth of invading vegetation and planted Engelmann spruce seedlings on the different microsites.

Forestry Canada, Pacific Forestry Centre, 506 W. Burnside Road, Victoria, British Columbia, Canada V8Z 1M5.

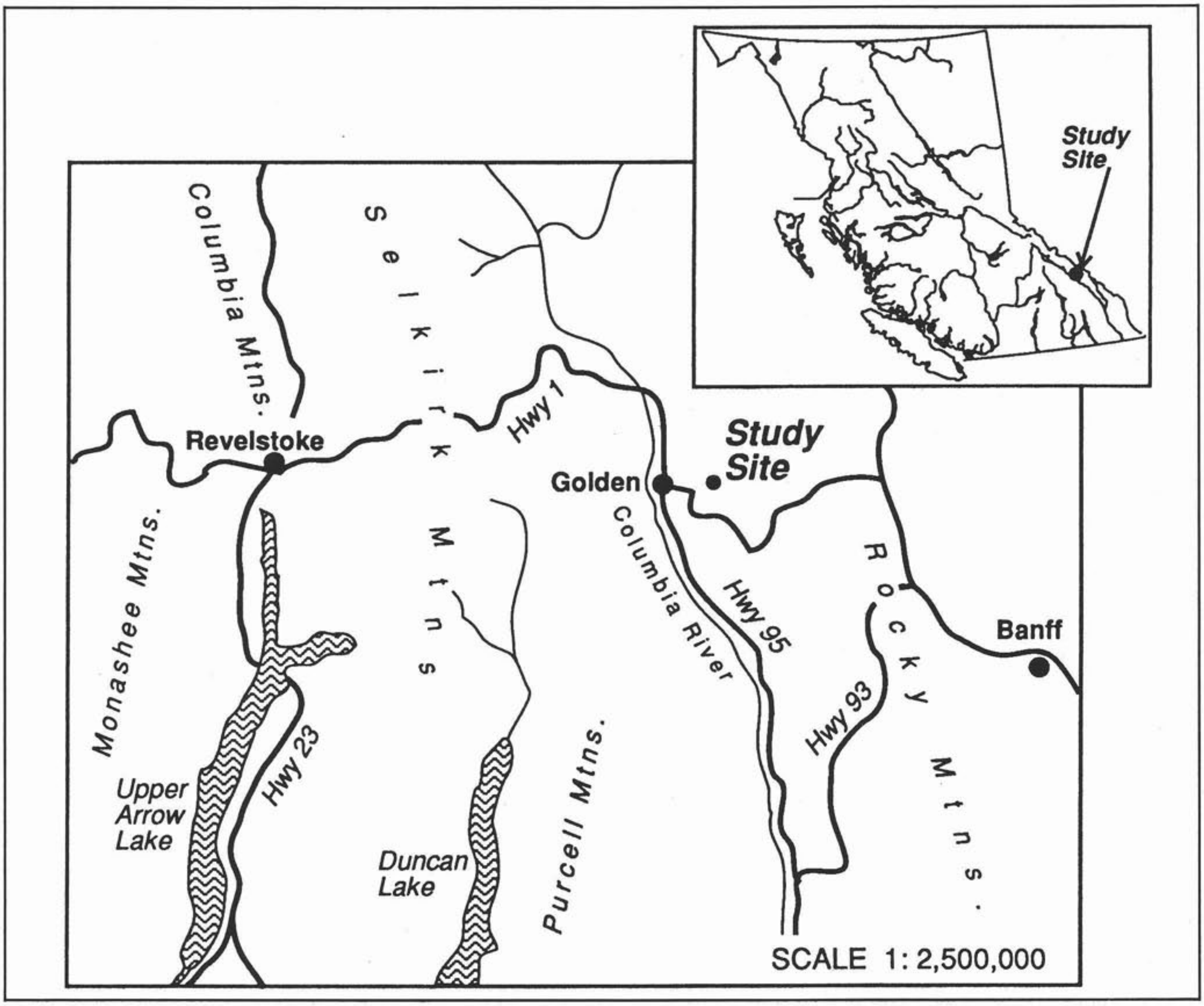

Figure 1. Study site location in southeastern British Columbia.

Methods

A 600-m base line was laid from near the bottom to near the top of the slope comprising the study area in such a manner that it crossed 23 skid trails. Ten of the skid trails were randomly selected for conducting vegetation succession analyses. At each site, four line-intercepts 10 m in length were located with origins close to the base line; one line-intercept was positioned on the sidecast, one in the middle of the trail, one on the cut-bank, and one in the burned area adjacent to the skid trail (Fig. 2). The line-intercept method (Larson 1958) for sampling vegetation was considered superior to rectangular plots because it permits separation for analyses of the vastly different site conditions created by the trail construction.

A metal conduit tube, which allowed the insertion of a metal rod, was driven in the ground at the end of each line-intercept. Rods 2 m in length were equipped with hooks at 30 cm and 90 cm from the top to allow attachment of a 10 m tape; the hook nearest the top was used for shrubs over a meter in height. A plumb bob was used to establish the intercept of woody plants above and below the tape. A 20 × 50 cm plot frame (Daubenmire 1959) was located at 0.0, 2.5, 5, 7.5 and 9.5 m along each line-intercept for ocular assessment of non-woody plant cover and counting the number of woody plant germinants (these are referred to as subplots henceforth). The two corners of these subplots that occurred under the intercept line were located with the plumb bob and

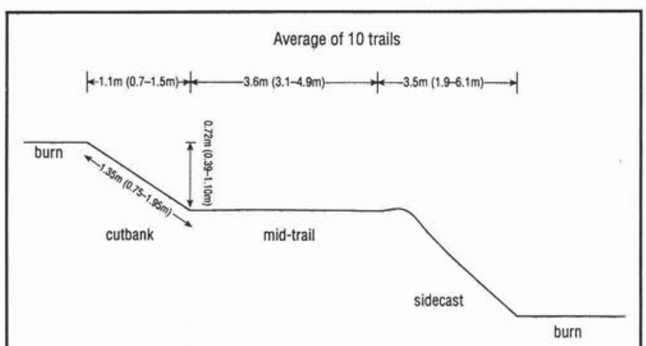

Figure 2. Position of skid trail and burned microsites; figures are average, widths, in meters, of skid trail components.

marked with nails to facilitate relocation; the subplots were always positioned on the right hand side of the line-intercept.

The physical site features of the general area, the line-intercepts, and each 20 × 50 cm subplot were recorded. This included such factors as slope, aspect and elevation for the general area, surface shape, position on slope, drainage, microtopography, surface materials and shape, and depth of organic matter if present for the line-intercepts and subplots.

The height, intercept length along line, length of leader, and basal diameter of each species of shrub or tree crossing the line-intercept were recorded. In the subplots, the percent cover, number, and height of each vascular plant species and the percent cover of each non-vascular species were recorded. Though the subplots were primarily for measuring non-woody species, the woody plant species had to be included in the measurements as they influence the non-woody species that may be in the subplots. Where present, five planted Engelmann spruce seedlings close to each line-intercept were chosen for measurement. The height, leader length, and basal diameter were measured on each seedling along with a notation of any feature that may restrict growth. Hitchcock *et al.* (1955-1969), Lawton (1971) and Vitt *et al.* (1988) references were used for the identification of vascular and non-vascular plants.

Meteorological data were obtained over a 3-year period from two 21X microloggers (Campbell Scientific, Inc., Edmonton, Alberta) located in scarified areas adjacent to the study sites, at approximately 1585 m and 1800 m elevation. Each micrologger was equipped with a Model LI200S Li-Cor silicon pyranometer, a Model LI190SB Li-Cor quantum sensor, a Model 12102 RM Young 3 cup anemometer, a Model TE525 Texas tipping bucket rain gauge, a Model 207 temperature and relative humidity probe in a radiation shield set at 1.3 m above ground, Model 107 temperature probes set at +5 cm, −5 cm, −10 cm, and −20 cm in the ground, and a Model 227 soil moisture block set at −10 cm. Soil temperatures were taken under 6 cm of duff plus about 30 cm of scattered slash debris, and under bare soil in a linear scarified patch about 3 m wide. The wind and sunlight sensors were mounted on a 3 m tall instrument tripod. The microloggers were equipped with tape recorders and housed in water proof and insulated shelters.

Results

Invasion of vegetation commenced the spring following the autumn burn and it occurred in all four sample sites. Fireweed (*Epilobium angustifolium* L.) was the most consistently present vascular plant (Table 1), occurring in 100%, 100%, 92%, and 94% of the slash burn, sidecast, mid-trail, and cutbank subplots, respectively. The highest percent cover of fireweed occurred on sidecast material (Fig. 3). Black huckleberry (*Vaccinium membranaceum* Dougl.) occurred in 60% of the burn subplots, but only in 20%, 16%, and 8% of the sidecast, mid-trail, and cutbank subplots respectively (Table 1); it also had a much higher frequency in the line-intercepts on burned sites than on the trails. Natural tree seedlings were also present within 1 year following burning. Engelmann spruce was present in 2% of the burn subplots, 4% of the sidecast, 10% of the mid-trail, and 12% of the cutbank subplots. Subalpine fir occurred in 14%, 4%, 12%, and 26% of the burned, sidecast, mid-trail, and cutbank subplots respectively. *Marchantia polymorpha L.*, *Ceratodon purpureus* (Hedw.) Brid., and *Polytrichum juniperinum* Hedw. were also initiated the first year following the burn and occurred on the exposed mineral trail beds as well as the burned surface.

The number of species and the cover they provided increased over the next 4 years (Fig. 4), with the most dramatic and dominating initial increase being in fireweed. Fireweed likely all started from seed, based on its rosette form the first year. By the third year, it was present along all line-intercepts and occurred in 95% of the subplots. Mean height growth of fireweed peaked on the fourth year being over one meter on the sidecast and between 60 cm and 90 cm on the

Table 1. Percent presence and cover for the more common species on each planting site after 5 years

Species	Slash burn	Sidecast	Mid-trail	Cutbank
Abies lasiocarpa	14 / 0.6[1]	4 / 0.1	12 / 0.4	26 / 0.5
Picea engelmannii (planted)	40 / 10.9	52 / 7.5	28 / 5.6	54 / 6.4
Picea engelmannii (natural)	2 / 0.1	4 / 0.1	10 / 0.1	12 / 0.1
Populus tremuloides	0 / 0	4 / 0.1	6 / 0.1	2 / 0.1
Populus trichocarpa	0 / 0	0 / 0	4 / 0.2	0 / 0
Ribes lacustre	2 / 0.1	0 / 0	2 / 0.1	0 / 0
Rubus idaeus	6 / 0.2	2 / 0.4	0 / 0	0 / 0
Salix spp.	0 / 0	2 / 0.4	8 / 0.5	14 / 0.6
Vaccinium membranaceum	60 / 11.5	20 / 1.6	16 / 2.3	8 / 0.4
Sambucus racemosa	12 / 0.8	4 / 1.0	0 / 0	0 / 0
Anaphalis margaritacea	2 / 0.1	2 / 1.2	4 / 0.1	4 / 0.1
Arnica cordifolia	0 / 0	2 / 0.1	2 / 0.1	4 / 0.3
Cornus canadensis	34 / 5.2	8 / 1.6	8 / 0.3	2 / 0.1
Epilobium angustifolium	100 / 19.2	100 / 55.4	92 / 26.1	94 / 18.6
Epilobium glandulosum	0 / 0	2 / 0.1	46 / 0.3	36 / 0.2
Erigeron acris	2 / 0.1	6 / 0.1	6 / 0.1	2 / 0.1
Hieracium albiflorum	2 / 0.1	0 / 0	2 / 0.1	6 / 0.1
Ceratodon purpureus	94 / 19.1	96 / 43.1	98 / 42.1	98 / 31.4
Marchantia polymorpha	16 / 0.5	14 / 0.2	24 / 0.3	42 / 1.9
Polytrichum juniperum	56 / 8.0	52 / 3.5	56 / 8.6	88 / 27.0
Pleurozium schreberi	2 / 0.1	4 / 0.1	10 / 0.4	14 / 0.7

[1]The number in front of slash is the Percent Presence, or the percent of plots in which the species occurred; the number behind the slash is the Mean Percent Cover.

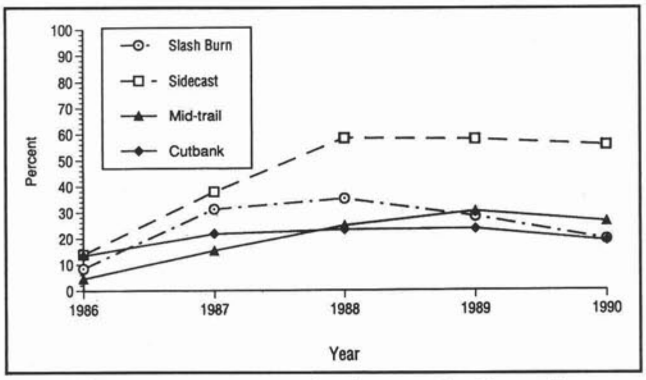

Figure 3. Mean percent cover by site type for fireweed.

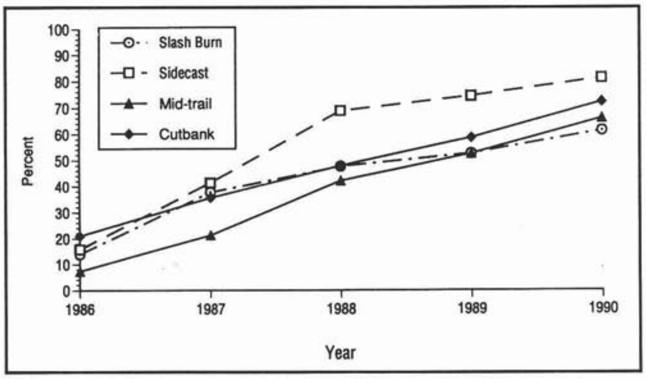

Figure 4. Mean percent cover by site type for all vegetation.

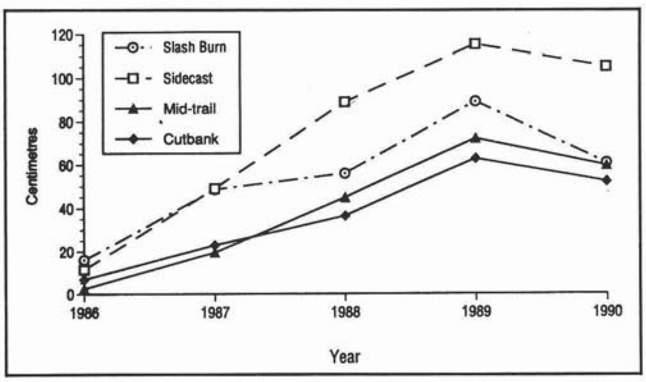

Figure 5. Mean height by site type for fireweed.

other sites (Fig. 5). The percent cover began to decline in the third year and the height declined in the fourth year. This trend was most dramatic on the burned areas where the mean height went from 88 cm to 60 cm between the fourth and fifth years and mean coverage went from 36% to 19% from the third year to the fifth year. However, despite these reductions, fireweed still dominated the landscape after 5 years.

Black huckleberry was the most prevalent shrub, particularly on the burn, but was slow to develop. After 3 years on the burn, the percent cover was 3% and this increased to 6.7% in 4 years and 11.5% in 5 years. On all three site types associated with the skid trails, the percent cover was less than 3% after 5 years, and was highest on the mid-trail site. The height increase was also gradual and attained nearly 23 cm in 5 years on the burn.

After 5 years, planted Engelmann spruce seedlings had survival rates of 93%, 96%, 98%, and 96% on the burn, sidecast, mid-trail, and cutbank sites respectively (Table 2). In the same sequence, mean total height was 94.4 cm, 77.5 cm, 68.4 cm, and 52.9 cm after 5 years (Fig. 6). Height growth was similar on all microsites in the first year, but decreased in the second year, especially on the skid trails. Growth increased in subsequent years but differed among the microsites. This growth trend is also revealed by the leader elongation (Fig. 7) where the leader responds to nursery conditions the first year followed by the establishment year, and then to the site. The best leader growth occurred on the burn (mean = 20.5 cm in fifth year) followed by the sidecast (17.4 cm), mid-track (15.7 cm) and the cutbank (9.6 cm). Increase in mean root collar diameter followed the same trend as the height and leader growth, and after 5 years amounted to 1.8 cm, 1.4 cm, 1.5 cm, and 1.2 cm on the burn, sidecast, mid-trail, and cutbank sites respectively. The slightly larger root collar diameter when compared to leader elongation in the mid-trail rather than the sidecast sites is probably due to the denser cover and competition by fireweed on the sidecast site which resulted in slender tree forms in relation to other sites.

Other environmental factors influencing seedling development and growth include vegetation competition which was high on the sidecast with 33% of seedlings being adversely effected (Table 2). Stem deformity was highest on the cutbank site, largely due to slumping of the bank; this was likely the greatest factor in reducing height growth and causing chlorosis of these seedlings. There appeared to be a greater incidence of Cooley spruce gall aphid on the mid-trail site, but the reason for this is unknown. Similarly the incidence of multiple tops had a marginal relationship with microsite, being most common on the mid-trail and burn sites and least on the sidecast.

Mean monthly climatic data recorded near the study area are presented (Table 3). Precipitation during the May to September period was 351 mm at the lower station (1585 m elevation) and 368 mm at the upper station (1800 m elevation). Snowfall was not recorded, thus annual precipitation could not be determined; it is estimated at about 1000 mm based on surrounding climate stations. Soil temperatures remain near the freezing level during the winter while the air temperature dips considerably below zero (Table 3); this is attributed to the snow pack insulating the ground from freezing. Also, the organic matter on the soil surface insulates the soil, resulting in generally lower temperatures throughout the year than in exposed mineral soil.

Discussion

Seedling development during the 5-year period, based on height and leader growth, over the sample sites followed the sequence: slash burn > sidecast > mid-trail > cutbank. This sequence was similar to what Smith and Wass (1979) reported for two out of eight study areas after 17 and 12 years in their study, but their study was conducted on natural regeneration following clearcutting with no site preparation. Two possible reasons for the best planted seedling growth occurring on the burned surface are the release of nutrients caused by the fire and the increase in soil temperature resulting from the blackened surface. These factors are considered influential in the seedlings developing bigger root

Table 2. Growth factors of planted Engelmann spruce over 5 years

Site treatment	Slash burn	Sidecast	Mid-trail	Cutbank
Number of seedlings	57	54	55	51
Average height at fifth year (cm)	90.8	75.9	68.4	52.8
Seedling condition		**Percent**		
Alive	93	96	98	96
No visible injuries	63	48	57	31
Cooley spruce gall aphid	6	2	13	8
Chlorosis	2	2	2	10
Multiple tops	21	15	24	18
Vegetation competition[1]	8	33	2	0
Stem deformed	0	0	2	33

[1]This is the percent of seedlings that were over-topped by non-crop species, mostly fireweed.

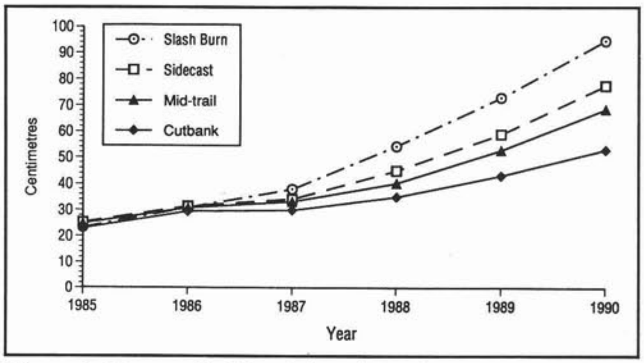

Figure 6. Mean total height of planted Engelmann spruce seedlings on each site type.

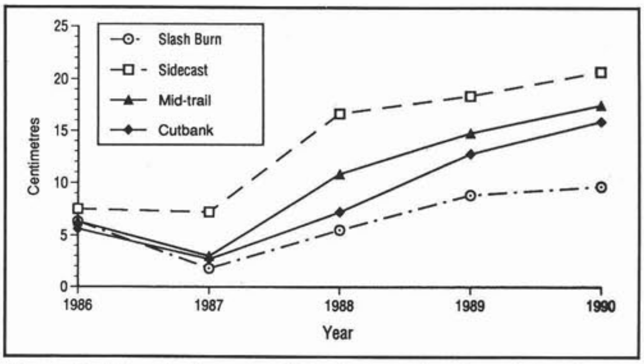

Figure 7. Mean leader growth by site type for planted Engelmann spruce.

systems during the initial establishment phase, which resulted in subsequent increases in growth rates, in comparison to seedlings planted in other microsites. The ash layer may have formed an inhospitable environment for establishment of invading species and thus delayed any competition to the planted seedlings. The primary invader, fireweed, did not establish the year following the burn to the extent it did on the trail, except for the mid-trail site (Fig. 3). Subsequent fireweed development on the burn, however, was exceeded only by the sidecast site in percent cover (Fig. 3) or height (Fig. 5). The higher mortality of tree seedlings planted on the burned sites (Table 2) is attributed to the deceased being planted too deep.

The sidecast material provided the best medium for seedling growth among the skid-trail sites. This material is loose in relation to the scrape face, and contains the organic and upper soil material from the scrape. The moisture regime of the area, due to precipitation distribution, snow pack, and aspect, is such that the soils rarely if ever become dry, and never get to the permanent wilting point. There are, however, several potential problems with planting in sidecast material. A soil covering over coarse woody debris can result in an air pocket in which seedlings can not survive if the roots are placed in this environment. The material on the outer lip of the sidecast is prone to sloughing and water erosion, particularly prior to the development of a vegetative cover. The favorable aspects of the site are also conducive to the development of competing vegetation. The main factor influencing the sampled seedlings is competition by fireweed; however,

Table 3. Climatic data recorded at the upper site in the Glenogle study area. Figures are monthly averages of data recorded hourly and stored as mean daily calculations over a three year period

Month	Temperatures +130[1]	−5s[1]	−10s	−20s	−10us[1]	−20us	GDD[1]	Solar[1]	PAR[1]
Jan.	−10.0	0.5	0.7	0.7	0.1	0.3	0.0	52.1	109.1
Feb.	−9.8	0.4	0.6	0.6	0.1	0.2	0.0	142.2	275.5
Mar.	−4.1	0.4	0.6	0.5	0.1	0.2	1.8	308.7	608.6
Apr.	1.6	0.5	0.6	0.5	0.1	0.2	24.6	438.0	870.9
May	5.0	1.6	1.6	1.2	0.4	0.4	55.1	490.1	984.8
Jun.	10.3	10.6	9.8	9.2	6.6	6.1	166.5	532.3	1055.4
Jul.	12.3	12.7	11.9	11.4	9.0	8.6	228.6	597.9	1166.4
Aug.	10.3	11.5	11.1	10.9	8.9	8.7	168.4	465.4	911.4
Sep.	8.4	8.0	8.0	7.8	6.9	6.9	124.8	357.9	692.5
Oct.	2.7	2.7	3.00	3.2	3.3	3.5	35.6	189.5	376.0
Nov.	−4.5	0.8	1.0	1.1	0.9	1.2	0.0	62.0	132.8
Dec.	−8.9	0.6	0.8	0.8	0.3	0.5	0.0	35.4	83.8

[1] +130 = air temperature at 1.3 m; −5, −10, −20 are soil temperatures at centimeters below ground surface; s = scarified with organic material removed; us = unscarified with organic layer left intact; GDD = growing degree days above 5°C; Solar = solar radiation, mean monthly in MJm^{-2}; PAR = photosynthetically active radiation ($E\ s^{-1}\ m^{-2}$).

most seedlings react with a spindly growth form and dark green coloration. The net effect must be assessed after several more years of development.

The most prominent growth inhibitors for seedlings planted on the cutbank side of the trail were the incidences of bank sloughing and delayed snow melt. Seedlings were most often planted in the middle to lower part of the bank which usually had the greatest expression of sloughing and snow retention. The results were seedlings with root cylinders bent horizontally, "J" shaped, or with tops curved downslope while the bottoms remained pointed downwards. Frost heaving sometimes added to the sloughing, mostly during the first year, and the seedling root cylinder was pushed out of the ground exposing 1–13 cm of the root cylinder. The chemical and physical properties of the cutbank soils varied with depth of cut; soils on shallow cuts were often characteristic of the B horizon, while those on deep cuts were more like the chemically poor C horizon. This was often revealed by the chlorotic appearance of the seedling. Other seedlings were more susceptible to insect damage such as the Cooley spruce gall aphid (*Adelges cooleyi* Gill.).

Seedlings were planted only occasionally in the mid-trail position, and most often this was where the skid trial went over a convex surface. Exposed C horizon material was a prominent feature along most of the mid-trail position, at least on deeper cuts. There was no competition to the seedlings for the first two or three years because invading plants were slow in getting established. Growth of planted tree seedlings were consistent with those in the sidecast for the first 2 years following planting, and then lagged somewhat during the third year (Fig. 6). The growth rate during the next 2 years was similar to the sidecast (Fig. 7), but the difference resulting from the third year remained.

The growth among seedlings planted on the sidecast was generally good (Figs. 6 and 7), with the main restriction being due to competition from fireweed. Based on mean growth rates of seedlings on the sidecast and mid-trail sites, the seedlings in the mid-trail site did relatively better than expected since the central part of the trail was considered to consist mostly of nutrient poor, C horizon material. It will be necessary to continue monitoring the seedling growth rates over several decades to see if current trends continue.

If seedlings are planted in the sidecast, mid-trail, and cutbank sites at a linear spacing along each line of about 3 m, the operational spacing distance, the total density along the trail will be too high, assuming a survival rate of 90% or more. Since there is a 42% reduction in seedling height growth (Fig. 7) on the cutbank site in comparison to the burned sites after 5 years, it seems appropriate to omit the cutbank planting sites. Perhaps the seedlings destined for planting on the mid-trail site could be moved immediately adjacent to the inner track. Though seedling performance on this site has not been tested, growth would likely be only slightly less than what was experienced for the mid-trail site. The main factors limiting growth at this site would be the nutrient-poor soil material and the colder soil regime caused by the more persistent snow pack and the shadowing on a northeasterly aspect.

Within the conditions of the study area, both from the stand point of site characteristics and operational forestry practices, competing vegetation had little influence on the planted Engelmann spruce seedlings. Fireweed was the most prominent invader, but even it did not pose a threat to the seedlings for the first 2 years. The burn intensity appeared to be moderately hot in that only coarse woody debris was left and the shrub tops were removed to ground level. This degree of burn appears adequate to retard shrub root stalk sprouting and development sufficiently to allow planted seedlings the opportunity of out-growing subsequent shrub growth. The main competition for space occurred in the sidecast material, yet seedling growth here was second only to that of the burn. If the decline in fireweed cover measured between the fourth and fifth years continues, the tree seedlings should respond with improved growth.

Loss in site productivity caused by the harvesting operation is related to the difference in growth performance of seedlings planted on the trails and those planted on the undisturbed, but burnt, portion. After five growing seasons, the reduction in height growth, compared to the burned area, was 18%, 28%, and 44% for the sidecast, mid-trail, and cutbank, respectively. Assuming that 30% of the area is disturbed for skid trail purposes (Smith and Wass 1979), then the indicated loss in productivity for the block is about 10%, using the burned area as a zero loss reference. Additional time is required to see if the magnitude of this trend continues, or if seedlings planted on any of the trail sites catch up to those planted on the burn. The next critical period could be when the seedling leaders extend above the winter snow pack.

References

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33: 43-64.

Hitchcock, C.L., A. Cronquist, M. Ownbey and J.W. Thompson. 1955-1969. Vascular Plants of the Pacific Northwest. Univ. Washington Press, Seattle. 5 Vols.

Larson, R.W. 1958. Use of transects to measure low vegetative cover. pp. 48-54 *In*: Techniques and Methods of Measuring Understory Vegetation, Proc. Symp. U.S.D.A. For. Serv., South. For. Exp. Sta. 1959. 174 p.

Lawton, E. 1971. Moss Flora of the Pacific Northwest. The Hattori Botanical Laboratory, Nichinan, Japan. 362 p. + 195 plates.

Meidinger, D.V. and J. Pojar. (Comp. & Editors). 1991. Ecosystems of British Columbia. B.C. Min. For., Spec. Rep. Ser. No. 6. 330 p.

Smith, R.B. and E.F. Wass. 1976. Soil disturbance, vegetative cover and regeneration on clearcuts in the Nelson Forest District, British Columbia. Fish. and Environ. Can., Can. For. Ser., Pac. For. Res. Cen., BC-X-151. 37 p.

Smith, R.B. and E.F. Wass. 1979. Tree growth on and adjacent to contour skidroads in the subalpine zone, southeastern British Columbia. Environ. Can., For. Serv., Pac. For. Res. Cen., BC-R-2. 26 p.

Smith, R.B. and E.F. Wass. 1980. Tree growth on skidroads, on steep slopes logged after wildfires in central and southeastern British Columbia. Envir. Can., For. Serv., Pac. For. Res. Cen., BC-R-6. 28 p.

Vitt, D.H., J.E. Marsh and R.B. Bovey. 1988. Mosses, Lichens, and Ferns of Northwest North America. Lone Pine Publ., Edmonton, Alta. 296 p.

Wittneben, U. and L. Lacelle. 1978. The Columbia Mountains and the Southern Rockies. p. 135-147 *In* K.W.G. Valentine, P.N. Sprout, T.E. Baker and L.M. Lavkulich. Editors. The soil landscapes of British Columbia. Res. Anal. Br., B.C. Min. of Environ. Victoria, B.C. 197 p.