ECOLOGICAL CLASSIFICATION OF ALBERTA FORESTS AND ITS APPLICATION FOR FOREST MANAGEMENT

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ABSTRACT: A forest-ecosystem classification for a 4.6 x 10^6-ha west-central Alberta study area was designed using several available sources of vegetation, soil, and forest-productivity information. Management interpretations using available ecological classification and reconnaissance soil-survey information were made for the following management concerns: harvest season and method; site-preparation intensity; soil-compaction, puddling, and erosion hazards; reforestation species, method, limitation, frost-heave hazard, and seedling-transplant mortality; site productivity; fire hazard; vegetation-competition hazard (type and severity); windthrow hazard; rodent-damage hazard; and common soil map units for each of twenty-five ecosystem associations.

INTRODUCTION

In recent years a greater appreciation of the value of forested land by a variety of potential users has intensified interest in ecosystem classification, evaluation of variation in forest site productivity, and in inventories of rapidly changing landscapes. Early forest-site research in the boreal forest of Alberta, Saskatchewan, and Manitoba has fallen behind other parts of Canada and the United States mainly because only recently (the last 25 years in Alberta) has any real utilization demand been put upon that forest region. The growing concern that forest resources are being depleted too rapidly or are being managed in a suboptimal manner is prompting the search for means to utilize most effectively the forest resource while maintaining its productivity.

Some of the earliest work in the western boreal forest was done in Alberta by Brinkman (1931, 1936) using lichens and mosses as site indicators. Smithers (1956) assessed site productivity in dense lodgepole pine stands in the Kananaskis Forest Experiment station, Alberta. Duffy (1964) used multiple-regression techniques to find relationships between site factors and growth of lodgepole pine in the Alberta foothills. Duffy (1965) developed a forest-land classification for the Mixedwood Section of central Alberta on the basis of differences in soil parent material and soil-moisture status as they influence white spruce site index. Dumanski et al. (1973) evaluated the productivity of lodgepole pine forests using soil-survey maps for the Hinton-Edson area. Lesko and Lindsay (1973) related lodgepole pine and white spruce site index within fifteen forest types to soils in the Chip Lake map area in westcentral Alberta. In addition, several descriptions of vegetation distribution in northern and northwestern Alberta have been made by Lewis et al. (1928), Dowding (1929), Raup (1933, 1934, 1946), Moss (1953, 1955), Moss and Pegg (1963), LaRoi (1967), Achuff and LaRoi (1977), Corns (1978), and, most recently, by Krumlik et al. (1978) during a biogeoclimatic classification of Alberta's forests and also during a biogeoclimatic classification of the British Columbia Forest Products Forest Management Agreement Area (Krumlik et al. 1982). Comprehensive reconnaissance soil surveys and interpretations for the study area have been made by Dumanski et al. (1972), Twardy and Corns (1980), and Knapik (1983).

The objectives of the present study were to classify and describe ecological zones (ecozones) and their component forest ecosystems within the study area with respect to their floristic composition, environmental characteristics, successional relationships, and potential for fiber production, and to make interpretations for forest management. All available, relevant sources of vegetation, soils, and climate information were consulted and, if possible, incorporated into the present classification and interpretations.

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The classification is a hierarchical system that corresponds to the biogeoclimatic system developed in British Columbia by Krajina (1965) and students; it also parallels the scheme used by the Canadian Committee on Ecological Land Classification (CCELC). The system used in western Alberta uses four fundamental classification levels: ecozone, subzone, ecosystem association, and ecosystem-association phase. The ecozone corresponds to the biogeoclimatic subzone as used in British Columbia (Krajina 1965, Pojar 1983), the ecoregion of Strong and Leggatt (1980), and the forest section of Rowe (1972). The ecozone defines a geographic area that is controlled by the same regional climate (macroclimate) and by characteristic zonal soils and vegetation that have developed in response to climate. The subzone, a subdivision of the ecozone, is similarly controlled by macroclimate, but it exhibits less variability in soils and vegetation. Ecosystems at the level of the biogeocoenose of Sukachev and Dylis (1964) are grouped into ecosystem associations which resemble the plant association of Braun-Blanquet (1928) and the habitat type of Daubenmire (1952). Ecosystem-association phases are not a taxonomic category in the ecosystem-classification system but are recognized in order to facilitate more precise resource-management interpretations. Phases of an ecosystem association are distinguished on the basis of differences in physiographic features (slope per cent, slope position, aspect, etc.) soil properties (i.e. texture), parent materials, and bedrock geology (Mitchell and Green 1981). Ecosystem associations and phases are considered to be the most-practical operational units and all management considerations are evaluated at this level.

STUDY AREA

Location and Extent

The study area is located in west-central Alberta between latitudes 53° - 55° N and longitudes 116° - 120° W. The area includes four National Topographic Series map sheets: Wapiti (83L), Iosegun (83K), Hinton-Edson (83F), and part of Mount Robson (83E, fig. 1) comprising an area of approximately 4.6 x 10^6 ha.

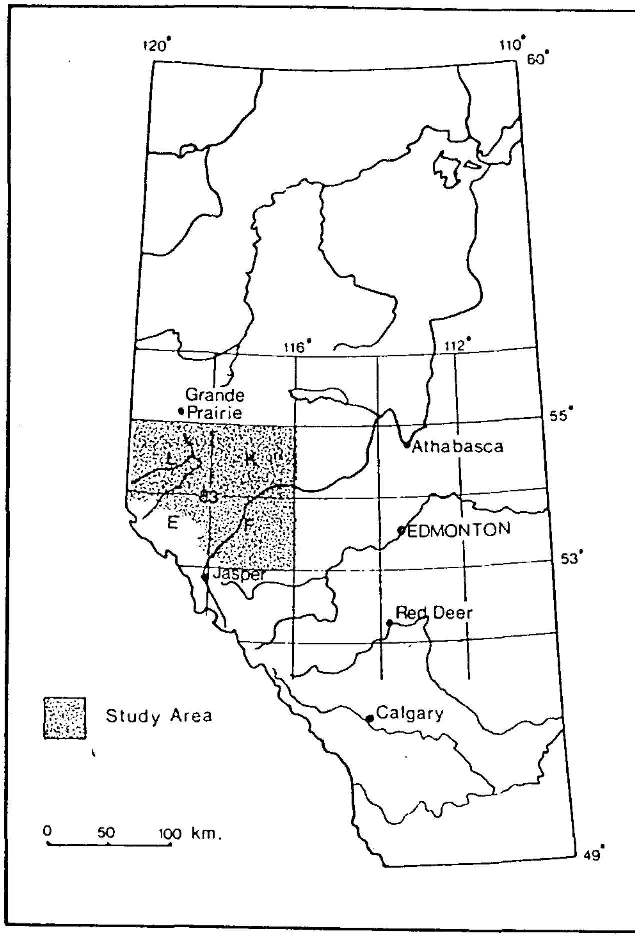

Figure 1.–Location of the Alberta study area.

Physiography, Geology, and Soils

The predominant physiographic regions in the study area are in the Alberta Plateau (Bostock 1970) and the Rocky Mountain Foothills. The area is underlain primarily by the Paskapoo Formation of Paleocene to Late Cretaceous age and consists of weakly consolidated beds of shale, sandstone, coal, and chert conglomerate.

Both Cordilleran and Keewatin (Continental) glacial ice-covered parts of the study area. The influence of the Cordilleran ice was restricted to the south and west and affected over one-third of the study area. The remainder of the area was covered by the Keewatin ice sheet in at least two ice advances. Surficial deposits include glacial till of Keewatin and Cordilleran origin occurring as ground moraine, glaciolacustrine silts and clays with bedding, glaciofluvial coarse gravels occurring as river terraces, aeolian sands, recent alluvial deposits, and organic peat. A few small areas of shale, sandstone, coal, and conglomerate outcrops are present in the more mountainous areas in the southwestern portion of the map area. Elevations range from 600 to 2450 m ASL.

Soils of the Luvisolic, Brunisolic, Gleysolic, Regosolic, Podzolic, and Organic orders of the Canadian soil classification system (Canada Soil Survey Committee 1978) are represented in the study area. The dominant soil subgroups are Orthic Gray Luvisols, Brunisolic Gray Luvisols, Gleyed Gray Luvisols, Podzolic Gray Luvisols, and Orthic Eutric Brunisols (Boralfs, Aqualfs, Atalfs, Cryochrepts, and Eutrochrepts. (Soil Survey Staff 1975).

More detailed descriptions of the nature and extent of the soils in this area are discussed by Knapik (1983), Twardy and Corns (1980), and Dumanski et al. (1972). These reports are accompanied by 1:126,720 scale maps.

Climate

Köppen's classification of climate describes the study area as a cold snow forest (Stringer 1972). This climate is characterized by cool summers and cold winters. The May 1 to September 30 period has a mean air temperature of 10-11°C, an average precipitation of 38-46 cm, 25-50 per cent of which falls as snow between November and March, a potential evapotranspiration of 38-43 cm, and a frost-free period (greater than 0°C) of 60 to 160 days (MacIver et al. 1972). Mean January air temperature (mean of daily max. and min.) at Edson is -14.0°C. Grande Prairie to the north of the study area is colder (-17.3°C), and mean monthly air temperatures are below freezing for all stations between November and March inclusive (Environment Canada 1975).

Vegetation

Most of the forest vegetation of the study area lies within the Mixedwood (B 18a), Lower Foothills (B 19a), and Upper

Table 1--Examples of management interpretations from ecosystem classification

Ecosystem association	Season[1]	Method[2]	Site preparation intensity[3]	Soil compaction hazard	Soil puddling hazard	Soil erosion hazard	Reforestation interpretations: Species[4]	Reforestation interpretations: Method	Reforestation interpretations: Limitations	Reforestation interpretations: Frost heave hazard	Reforestation interpretations: Seedling transplant mortality
Lower Boreal Subzone:											
Picea glauca/Equisetum arvense/Hylocomium splendens	W	CC PC	H	H	M-H	M-H	wS	Bare-root	Excess moisture	H	H
Populus tremuloides/ Vibernum edule/Aralia nudicaulis	S	CC	M-H	H	M-H	H	A, wS, lP	Bare-root, container	Excess moisture, fine texture	M-H	M
Pinus contorta/Elymus innovatus	S	CC	L	L	L-M	L-M	lP, A	Natural seed, container	Drought	L	M
Upper Boreal Subzone:											
Pinus contorta/Alnus crispa/Cornus	S	CC	L-M	M	L-M	L-M	lP wS	Container, natural seed	Competition	M	L-M
Pinus contorta-Picea mariana/Ledum groenlandicum/ Pleurozium schreberi	S	CC	L-M	M-H	M-H	M-H	lP	Container, natural seed	Excess moisture on some sites	M	L-M
Pinus contorta/ Vaccinium myrtilloides/ Cladonia spp.	S	CC	L	L	L	L	lP	Container, natural seed	Drought	L	M
Subalpine Zone:											
Pinus contorta/ Rhododendron albiflorum/ Rubus pedatus	W	CC	L-M	M	M-H	M-H	lP	Container	Excess moisture in spring	M-H	M

[1] Season: W - winter; S - summer
[2] Method: CC - clearcut; PC - patch cut; SC - selective cut
[3] Site Preparation intensity and others: H - high; M - medium; L - low
[4] Species: wS - white spruce; lP - lodgepole pine; A - aspen; bS - black spruce

Foothills (B 19c) sections of the Boreal Forest Region plus a small area within the East Slope Rockies Section (SA 1) of the Subalpine Forest Region (Rowe 1972). These units correspond to the Boreal Mixedwood, Boreal Foothills, Boreal Uplands, and Subalpine Ecoregions mapped at 1:1,500,000 for Alberta by Strong and Leggat (1981).

METHODS

Plot Sampling and Classification

Data were obtained from approximately 900 sample plots from the following studies: Krumlik et al. (1978, 1979, 1982), Nemeth et al. (1981), Corns (1978), and Lesko and Lindsay (1973). Although the work of Lesko and Lindsay (1973) is from the Chip Lake map area adjacent to the southwest corner of the study area, it is relevant to much of the lower elevations of the study area farther north. The 0.01 to 0.04-ha sample plots were selected using forest-cover maps and aerial photographs within well-developed homogeneous forest stands on a variety of soils and landforms. In all the studies the sample plots were placed subjectively to best represent soil and vegetation conditions. Plot location and general physiography (elevation, slope gradient and aspect, topographic position, relief shape, and landform) were recorded on field sheets. Soils were described according to the Canadian System of Soil Classification (Canada Soil Survey Committee 1973-1978). Vegetation was sampled in a fashion compatible with Braun-Blanquets' (1932) methods or those described by Walmsley et al. (1980). Classification was done by tabular comparison (Mueller-Dombois 1974) using computer-generated vegetation and environment tables. Additionally, all sample plots included forest mensurational data. Site index was determined for all plots based on dominant and codominant trees, and for most plots stand volumes and mean annual increment in total volume (MAI) were also determined.

Interpretations for Forest Management

Interpretations for forest management (table 1) are made within an ecosystem association framework and are based upon a variety of information sources including reconnaissance soil-survey reports, available forest ecological information, and observations by operational foresters and the authors. Quantitative data were not available for many interpretations nor for some ecosystem associations. In these instances, data from similar environmental/ecological situations were extrapolated. Interpretations were made for a variety of attributes significant for forest management: season and method of harvest, site-preparation intensity, soil-compaction hazard; soil-pud-

Table 1–continued

		Productivity							
Ecosystem association	Species	X MAI	Site index (70)	Fire hazard[5]	Vegetational type	Competition severity	Windthrow hazard	Rodent damage hazard	Common soil map units
Lower Boreal Subzone:		(m³/ha/yr)	(m)						
Picea glauca/Equisetum arvense/Hylocomium splendens	wS	3.7	11.8	M-L M-L / M-L M-L	Reedgrass, sedge	M-H	H	M	SIP, SKY, GUN
Populus tremuloides/ Vibernum edule/Aralia nudicaulis	A	4.3	19.8	L-M L-M / H L-M	Reedgrass, forbs, willow	M-H	M	H	LDG, DON
Pinus contorta/Elymus innovatus	lP	3.4	16.0	M-H M-H / H M-H	Ryegrass	L	L	L	RBB
Upper Boreal Subzone:									
Pinus contorta/Alnus crispa/Cornus canadensis	lP	4.0	17.6	M-L M-L / H M-L	Alder, reedgrass	M	L	H	EDS, MLB TOR
Pinus contorta-Picea mariana/Ledum groenlandicum/ Pleurozium schreberi	lP	3.8	15.8	M-L M-L / H M-L	Reedgrass	L-M	M	M	EDS, SIP, TOR, COP
Pinus contorta/ Vaccinium myrtilloides/ Cladonia spp.	lP	1.3	11.9	L-M L-M / H L-M	Ryegrass	L	L	L	BKM
Subalpine Zone:									
Pinus contorta/ Rhododendron/albiflorum/ Rubus pedatus	lP	3.0	13.1	M-H M-H / H M-H	Reedgrass, Rhododendron	L	M	L	RBB, COP

[5] Fire hazard: cured dormant crown (early spring, late fall) active growth crown (late spring to early fall) / cured dormant surface (early spring, late fall) active growth surface (late spring to early fall)

Table 2–Optimum season of harvest

Season	Internal drainage	Texture B Horizon	Soil map unit
Winter only	Imperfectly to very poorly	CL-HC	DON1; SIP1, 2; EDS2; 2,3,4
Summer or winter	Rapidly to moderately well	S-CL	

dling hazard; soil-erosion hazard; reforestation method, limitations, preferred species, seedling frost-heave hazard, and anticipated seedling mortality; productivity in site index and MAI for dominant species; fire hazard; vegetational competition (type and severity); windthrow hazard; and snowshoe hare-damage hazard. Summary tables used in making interpretive evaluations are included in the following section.

RESULTS AND DISCUSSION

Ecosystem Classification

To date twenty-five ecosystem associations have been described for the west-central Alberta study area. The descriptions of these are the subject of another manuscript in preparation.

Management Interpretations

Management interpretations were made of nineteen forest management concerns using the ecological classification and reconnaissance soil surveys for the study area (table 1). A discussion of these follows.

Timber Harvest.–

A. Season: The recommended season of harvest (table 2) is designated as winter (W) when ground is frozen or summer (S) depending largely upon the wetness of the site and its ability to support heavy equipment without site degradation. Sites suitable for summer harvest are generally also suited for winter operations. All sites should be avoided during spring snow melt, when soil moisture is above field capacity.

B. Method: The harvest method includes both the method of falling the timber and the means of removing the fallen logs from where they were fallen.

Table 3–Logging method

Method	Tree cover
Large clearcut	Lodgepole pine, mixed pine, and spruce
Patch or strip cut	Even-aged spruce
Selective cut	Uneven-aged spruce

i. Logging Method (table 3) – Clearcutting (CC) generally proved to be a satisfactory method of harvest on a wide variety of forest sites in Alberta, particularly those cut for lodgepole pine pulpwood. Small (e.g. <20 ha) patch cuts (PC) are desirable in even-age spruce-dominated stands to facilitate spruce natural regeneration. In old growth and uneven aged spruce, selective cutting (SC) may be appropriate so that old trees are removed and younger trees are preserved and released as well as providing seed for natural regeneration. There are other methods and modifications available (e.g., seed tree, shelterwood) but these presently appear not well suited for most Alberta conditions, especially from an economic point of view.
ii. Log removal – The widely used rubber-tired skidders are satisfactory for most sites, although low ground-pressure track skidders (e.g., FMC) will minimize soil disturbance, compaction, and erosion on wet, fine-textured soils logged when the ground is not frozen. Heavy equipment such as feller-bunchers should be restricted to well drained, coarse-textured soils to minimize compaction or should be used during winter when soils are frozen.

Site-preparation intensity.–Site-preparation intensity recommendations (table 4) were made as low, medium, or high depending upon the environment (including soil properties), vegetation-competition hazard, and seed supply. Several options may be available to accomplish similar results. These are discussed below:

Low intensity: These sites are generally moderately well to rapidly drained, have shallow (>10 cm) soil organic layers, minimal plant-competition problems, and low to moderate slash abundance. Satisfactory lodgepole pine regeneration may be achieved on many sites with a good cone supply without site-preparation if the slash and cone are well distributed. Methods of low-intensity site preparation include the following:
a. Screefing (mattock, boot, spade). This may be appropriate when planting bare-root stock on topographically irregular sites, sites inaccessible to large machinery, sites where soil compaction may be a problem, and sites where plant competition, especially reedgrass (*Calamagrostis canadensis*), is well established and where more-severe site preparation may further stimulate competition.
b. Anchor-chain drags. This method gives satisfactory results on a wide variety of sites and scarification intensity and degree of coverage can be regulated by the number and length of the drags. Caution should be taken to minimize soil compaction on sites with fine soil texture or weak structure.
c. Toothed scarifier blade. The main concern should be to redistribute slash (cones) if necessary as the shallow organic layer should not pose a significant impediment to rooting seedlings. Soil compaction may be significant on fine-textured soils or on those with weak structure.

Moderate Intensity: These sites are moderately well to imperfectly drained, have moderately deep (10-15 cm) soil organic layers, moderate to high plant-competition ratings and low to moderate slash abundance. Methods of moderate-intensity site preparation include the following:

a. Shark-fin barrels. This equipment does a satisfactory job on level to gently sloping moist sites with moderate slash abundance and moderately deep organic layers. Degree of scarification can be regulated by the amount of fluid put in the drums as well as number and length of the attached anchor-chain drags.
b. Toothed scarifier blade. This equipment on a large tractor (e.g., Caterpillar D6 and larger) is capable of spreading large amounts of slash and penetrating deep organic layers.
c. Bracke scarifier. This machine can provide good results on wet sites or where plant competition is a problem and can provide planting sites with a wide range of moisture regimes.

High Intensity: These sites are poorly to imperfectly drained, with deep (15-30 cm) organic horizons, generally high plant-competition ratings and low to high slash abundance. Methods of severe-intensity site preparation include the following.

a. Martinni plow. This rear-mounted plow is capable of exposing mineral soil on wet sites with deep organic layers. Its relatively large size and weight make it more difficult to maneuver and increase the chances of getting stuck with resulting soil damage compared with alternative equipment. Chances of subsoil glazing and compaction are greater with the Martinni plow than with some other "severe" methods (e.g., the ripper plow). Flooding of the furrow is a problem on very wet sites. Furrows should run parallel to slope contours to minimize soil erosion particularly during spring runoff and on fine-textured till and lacustrine materials. On very gentle, short slopes on less erodible materials (e.g., some tills), downslope orientation of the furrows could provide some drainage, with minimal erosion.
b. Ripper plow (Craig - Simpson, C & S). This plow and adaptations of it have proved to be versatile machines for site preparation on wet sites, requiring less energy than the larger Martinni and creating less disturbance of the site. The ripper plow is often used in conjunction with a brush rake or toothed scarifier blade to move heavy slash, particularly the presently unutilized hardwoods, into windrows.

Table 4–Site-preparation intensity

Intensity	Internal drainage	Vegetational competition	Slash abundance	Organic layer thickness	Soil map unit
				(cm)	
Low	Rapid to moderately well	Low	Low to moderate	< 10	COP1; SHP1,2; EDS1,2,3,4
Moderate	Moderately well to imperfectly	Moderate to high	Low to moderate	10-15	COP3; DON1 JUY1,2
High	Imperfectly to very poorly	High	Low to high	15-30	GUN1; KN2; SFP1,2

Table 5–Soil compaction hazard[1] (use chart from left to right)

Texture	Coarse fragments	L + F thickness	Structure	Character of coarse fragments	Soil map unit	Rating
	(%)	(cm)				
L,SiL, SiCL, CL, Si, heavy SL, vfSL	<35	<5	Strong	All	DON1; SIP1,2	Moderate
			Mod. & weak	All	EDS1; RBB7	Severe
		>5	Mod. & weak	All		
			Strong	All	RBB6; SHP1	Moderate
	35-60	<5	Mod. & weak	Rounded		
				Angular	SMT1; MBN4	Low
			Strong	All		
		>5	Mod. & weak	Angular		
				Rounded	ERR3; STT	Moderate
			Strong	All	COP1; CAW	Low
	>60	any	All	All		
LS,S	any	any	All	All		
SiC, C, SC, SCL	>35	any	All	All		
	<35	<5	Strong	All		
			Mod. & weak	All	COP3; BKM6	Moderate
		>5	Mod. & weak	All		
			Strong	All	ESH; LDM1	Low

[1] In making a rating, consider the characteristics of the litter and upper 30 cm of mineral horizon(s). A wet or moist condition is assumed. The horizon which gives the poorest rating is used. Table adapted from Boyer (1979).

c. Brush rake. This multitoothed bulldozer blade can effectively increase the receptive area for regeneration by putting heavy slash and unutilized hardwoods into windrows and by removing excess organic matter from the soil surface. As with other treatments that involve use of heavy equipment, soil compaction is likely to result.

d. Cazes and Heppner plow (C & H). This wide, front-mounted V-blade can effectively remove virtually all vegetational competition (including well-established trees) plus soil-organic and surface-mineral horizons. The resulting denuded surface can be very susceptible to erosion on slopes, especially where soils are fine textured. Soil compaction and glazing of the subsoil could also be anticipated on fine-textured soils. The edges of the bladed strips are usually the best sites for planting. In these situations, organic matter and nutrients are likely to be more abundant, and susceptibility to drought and frost heave is likely to be less. It is believed that less-severe scarification methods are probably adequate as preparation for planting on most sites and that the C & H plow should be restricted to areas of stable soils where stand conversion (e.g., aspen to lodgepole pine) is being attempted.

Soil interpretations.– Soils interpretations for the various ecosystem associations are based upon the predominant soils found with each type. Reconnaissance soil surveys, completed over most of the study area, have rated soil-mapping units for a variety of relevant interpretations, including soil-erosion hazard, windthrow hazard, and transplant mortality. Work done by others (Boyer 1979, Townsend 1982) has enabled ratings for soil compaction and puddling to be made for the predominant soils of each ecosystem type.

It must be recognized by the users of this manual that the ratings are general and relative and that variation outside the ratings in table 1 can be expected as the soils occurring with a given soil subgroup or map unit will have a range of properties. It is thus important to evaluate sites individually where site-specific information is desired. The ratings given in table 1 can be approximated by the operational forester by using the information and criteria provided below. The background information used to make the ratings comes from detailed sample-plot data plus relevant soil-survey reports (Twardy and Corns 1980, Dumanski et al. 1972, Twardy and Lindsay 1971, and Knapik 1983). Only relative ratings can be provided as quantitative data are scarce.

A. Soil compaction

The degree of soil compaction is influenced by a number of soil physical properties including texture, per cent coarse fragments, per cent organic matter, organic-layer thickness, structure, and the type of coarse fragments. Table 5 is adapted from Boyer (1979). Compaction reduces porosity and rate of water infiltration as well as increasing physical impedence to growing roots. The horizon which gives the poorest rating in the upper 30 cm of mineral soil will determine the rating for the soil. Most of the soils of the study area, particularly those of the Lower Boreal and Aspen-White Spruce zones are susceptible to compaction, moreso than those in the foothills within the Upper Boreal zone due to predominantly finer textures and fewer coarse fragments in the predominantly continental tills in the east.

Increased soil compaction has been shown to reduce forest productivity in many parts of the world. Quantitative data are not available for our area. Soil compaction can be minimized by keeping heavy machinery off the more susceptible soils when they are wet, by minimizing the area of logging roads or clearcuts, and by minimizing the number of passes over an area (Rothwell 1978). On susceptible soils, most compaction occurs during the first pass over the area by heavy equipment.

Table 6--Soil puddling hazard[1] (Use chart from left to right)

Texture	Coarse fragments	L + F thickness	Structure	Soil map unit	Rating
C, SiC, Si SiL, SiCL, SC, CL, vfSL	<35	≤5	Strong	DON1; SIP1,2	Moderate
			Mod. & weak	EDS1; RBB7	High
		>5	Mod. & weak		
			Strong	RBB6; SHP1	Moderate
	35-60	≤5	Mod. & weak		
			Strong	SMT1; MBN4	Low
		>5	Strong		
			Mod. & weak	ERR3; STT	Moderate
	>60	any	All	COP1; CAW	Low
LS, S	any	any	All		
L, SCL, SL	>35	any	All		
	<35	≤5	Strong		
			Mod. & weak	COP3; BKM6	Moderate
		>5	Mod. & weak		
			Strong	ESH; LDM1	Low

[1] In making a rating, consider the characteristics of the litter, and upper 30cm of mineral horizon(s). A wet soil condition is assumed. The horizon which gives the poorest rating is used. Table adapted from Boyer (1979).

Table 7--Soil erosion hazard[1]

Hazard	Parent material	Texture B horizon	Slope %	Soil map unit
Low	Till	Medium to coarse[2]	<10	RBB1
	Colluvium, glaciofluval gravels, unconsolidated bedrock (sandstone, shale), organic	Variable	<5	JUY1, 2;STT
Moderate	Till	Fine to moderately fine	<10	EDS1,2,3
	Till	Medium to coarse	10-15	LDG 1,2,4,5,6,8
	Till	Very stony variable texture	16-60	MBN1,7
	Colluvium	Variable	5-30	ERR3
	Eolian	Coarse	0+	HRT1,3; HTN1 to 8
	Unconsolidated bedrock	Variable	5-9	COP1
	Organic	--	5-9	KNZ
High	Glaciolacustrine	Fine	0+	DON1
	Glaciofluvial	Medium to coarse	0+, especially Gleysols	GUN1
	Till	Fine to moderately fine	>10	EDS4; MBN4
	Till	Medium to coarse	>15	SHP1,2
	Colluvium	Variable	>30	
	Unconsolidated bedrock	Variable	>10	COP3
	Organic	-	>10	KNZ

[1] Ratings assume unvegetated surface. Dense vegetation cover will reduce hazard by at least one class.
[2] Textural groups are as follows: fine—sandy clay, silty clay, heavy clay; moderately fine—clay loam, sandy clay loam, silty clay loam; medium—very fine sandy loam, loam, silt loam, silt; moderately coarse—sandy loams; coarse—sands, loamy sand.

Compaction effects can be long lasting in the Pacific Northwest. Under some conditions, the surface few centimeters of compacted soil will recover within a few years to a few decades. The deeper soil compaction appears to require substantially more time, and the rate of this recovery is still largely unknown (Froelich 1982). Less is known of soil-compaction effects for the Canadian boreal forest, where repeated freeze-thaw cycles may be expected to help ameliorate compaction damage. Winter logging and site preparation minimizes compaction and the desirability of restricting summer operations to well-drained, coarse-textured soils is emphasized. Soil compaction effects are discussed further in reviews by Lull (1959) and Froelich (1973, 1982).

B. Soil Puddling

Puddling is the soil physical condition that results from the dispersal of soil particles causing destruction of the soil structure and the formation of a dense crust on the soil surface. This crust has the same effect as a thin compacted layer, and is most common on soil surfaces where litter has been removed by burning or by mechanical means. Reduced germination and increased mortality may be expected on soils compacted or puddled by logging equipment (Pritchett 1979). Wet, fine-textured soils with few coarse fragments, shallow organic layers, and weak structure are most susceptible to puddling, while soils of any texture with thicker organic layers, abundant coarse fragments, and strong structure are least susceptible (Boyer 1979, table 6). The ratings given in table 6 make the assumption that the organic layer is < 5 cm. If the organic layer is >5 cm, a rating one class less severe (e.g., from moderate to low) would be applied.

C. Soil-Erosion Hazard

Soil losses from forested areas are normally very small. Increase in erosion and stream turbidity are due mainly to road construction and other activities that expose large areas of mineral soil (Pritchett 1979). There are many factors which influence the erodibility of soil and parent materials: texture, type of structure, degree of carbonate cementing (parent materials), stone content, amount and type of vegetation cover, slope angle, length of slope, occurrence of recent fire, rainfall intensity and seasonal distribution, and rapidity of snow-melt. Only water erosion is considered here. Wind erosion is generally not a problem in the study area with the possibile exception of some local soils in the Athabasca Valley southwest of Hinton. Infiltration capacity and structural stability are regarded as most important in controlling water erosion (Buckman and Brady 1960). Soil-erosion hazard is the expected rapidity and amount of soil loss due to wind and/or water that may be expected following removal of the protective vegetation cover in areas where the proper erosion-control measures are not implemented (Dumanski et al. 1972). Because of the many factors determining erodibility, generalized relative erodibility hazard ratings for soils under a plant association must be made assuming average rainfall intensity and rate of spring snowmelt using information published in reports by Dumanski et al. (1972), Twardy and Corns (1981), Knapik (1983) and Rutter (1968). Erosion will increase as slope steepens up to 80 per cent (40°); thereafter decreasing to zero as steepness approaches 200 per cent (90°) (Rutter 1968). Erosion will be greater on long slopes.

The relative erosion-hazard ratings described (table 7) are based primarily on soil texture, estimates of infiltration and permeability rates, soil structure, soil wetness, and slope angle, where surface organic layers have been removed.

a. Low – Parent materials (and soils developed on them) with a usually low erosion hazard include medium- to coarse-textured tills (slopes <10 per cent), colluvial materials (slopes <5 per cent), glaciofluvial gravels, unconsolidated bedrock (sandstones and shales; slopes <5 per cent), and organic soils (slope <5 per cent).
b. Moderate – Parent materials (and soils developed on them) with usually moderate erosion hazard include fine to moderately fine-textured tills (slopes <10 per cent), medium to coarse textured tills (slopes 10-15 per cent or up to 60 per cent if very stony), colluvial materials (slopes 5-30 per cent), aeolian deposits, unconsolidated bedrock (sandstones and shales; slopes 5-9 per cent), and organic materials (slopes 5-9 per cent).
c. High – Parent materials (and soils developed on them) with a usually high erosion hazard include glaciolacustrine deposits (any slope), glaciofluvial sands and silts (any slope – especially Gleysolic soils), fine- to moderately fine-textured tills (slopes >10 per cent), medium- to coarse-textured tills (slopes <15 per cent or steeper depending on stoniness), colluvial materials (slopes >30 per cent), unconsolidated bedrock (slopes >9 per cent), and organic materials (slopes >9 per cent).

Ratings of individual soil units mapped in the study area are available in reconnaissance soil surveys by Dumanski et al. (1972), Twardy and Corns (1980), and Knapik (1983).

Methods for minimizing erosion as a result of logging and road construction in Alberta are discussed by Rothwell (1978) and Lengellé (1976). A variety of practical "bioengineering" methods using vegetation as a means of stabilizing slopes and reducing erosion is discussed by Schiechtl (1980).

Reforestation Interpretations.–

A. Species selection

The species selected to reforest a site will depend upon both its biological and economic suitability. The latter is more difficult to judge since it is virtually impossible to know what forest products will be available to and desired by the consumer at the end of the rotation.

Clues to tree species biologically well adapted to a site can be determined from soil physical and chemical properties and the species (tree and understory) that occupy the site. Climate, soil-moisture regime, and to some extent nutrient regime can be inferred from the composition of the vegetation. Soil properties, particularly drainage and pH, will have a strong bearing upon the species selected for planting a site.

The current Alberta Forest Service Planning and Harvesting Ground Rules for Forest Management Area holders specify that tree regeneration on cut-over areas must average 1.8 to 2.5 m in height before adjacent trees can be removed in the second cut. This guideline appears to encourage reforestation using initially faster growing pine on sites that might be better suited to spruce production when the whole rotation period is considered. The rapid initial growth advantages of establishing pine rather than spruce may not result in the best economic yield or wildlife habitat in the long term.

The interpretations made for tree-species suitability consider only those species native to the study area and are based primarily upon the inferred ecological suitability of the site. Current markets for particular forest products have no bearing upon the interpretations The principal factors considered are climate, soil drainage, soil reaction (pH), organic-layer pro-

Table 8--Species selection for reforestation

Species	Elevation	Drainage	pH	Organic thickness	Texture	Soil map unit
	(m)			(cm)		
Aspen	<1100	Well to moderately well	5-7	<10	Heavy clay-loam	DON1; EDS1, 3
White spruce	600-1300	Well to imperfectly	4.5-7.5	<20	Heavy clay-loam	SIP1,2; ESH1; LDM1
Black spruce	600-1650	Well to poorly	3-6.5	10-30	Organic, heavy clay-sandy loam	KNZ; DVS1,2
Engelmann spruce	1300-1650	Well to imperfectly	4.5-7.5	<20	Clay loam-sandy loam	BKM3; ERR3; MSK4
Lodgepole pine	600-1650	Rapid to imperfectly	3-6	<10	Clay-loamy sand	EDS3; ERR1; HRT1,2,3,4
Balsam fir	600-1300	Well to imperfectly	4.5-6.5	10-20	Heavy clay-sandy loam	BKM6; DON2; SIP1
Subalpine fir	1300-1650	Well to imperfectly	4.5-6.5	10-20	Heavy clay-sandy loam	BKM3; ERR3; MSK4,5

Table 9–Reforestation method on cutblocks[1]

Site conditions	Seed availability[2]	Species/reforestation options				Soil map unit
		Lodgepole pine	White spruce	Black spruce	Aspen	
Soil moderately well to rapidly drained, organic layer generally <10 cm, vegetation competition not usually a problem	Abundant	Natural	Natural	Natural	Natural root suckers	COP1,3 EDS1,2,3,4
	Sparse	Container, aerial seed[3]	Container, aerial seed	Container, aerial seed	Natural root suckers	
Soil imperfectly or more poorly drained, organic layer generally >10 cm, vegetation competition often a problem	Abundant	Container, bare root, natural	Container, bare root, natural	Container, natural	N/A	SIP1,2 ETH1,2,3
	Sparse	Bare root, container	Bare root, container	Container	N/A	

[1] This table should be used in conjunction with Table 8.
[2] Seed abundance is a function of slash and cone abundance plus proximity to adjacent seed-producing trees (especially important for spruce).
[3] Aerial seeding will have best results when 40-60% mineral soil is exposed and soil moisture is near field capacity.

perties (principally thickness), soil texture, and knowledge of tree growth on various sites. Table 8 presents the basis for species selection. Most of the soil information can be determined for the area in question from the reconnaissance soil survey reports and accompanying maps (Twardy and Corns 1980, Dumanski et al. 1972, and Knapik 1983). All factors should be considered together when rating a site in order to select the best-suited species. On sites that are environmentally suitable for more than one species, anticipated future markets may determine the selection.

B. Reforestation Method

Reforestation method here refers to the means by which satisfactory tree stocking is achieved on logged areas. The alternatives are natural seeding from slash or adjacent trees, root suckers (aspen), manual or aerial seeding, containerized planting stock, and bare root planting stock (table 9). The situations applicable to the various options are discussed below:

Natural: a. Pine – Sites with good cone crops, soils that are moderately well or better drained, and organic layers less than 10 cm thick can generally be adequately restocked without additional planting. A light scarification might be necessary to distribute cones more evenly.
b. Spruce – Satisfactory natural spruce stocking is likely to be attained only on sites with a continuing seed source such as on small patch or strip cuts or where seed trees are left. Spruce stocking on such sites will be favored where mineral soil is exposed and moisture is neither limited nor in excess.
c. Aspen – Satisfactory natural aspen stocking is usually achieved by root suckering from cut trees without additional silvicultural input.
d. Balsam and subalpine fir – These species generally acheive satisfactory natural regeneration only under the canopy of other trees.

Direct Seeding: Satisfactory stocking results from direct seeding can be expected only where there is a large amount of exposed mineral soils (40-60 per cent), minimal vegetational competition, and enough moisture to ensure germination and seedling establishment. Timing of the seeding operation is crucial.

Table 10–Frost heave hazard

Hazard	Internal drainage	Mineral soil exposure	Texture B horizon	Slope position	Soil map unit
		(%)			
Low	Rapidly to well	0-25	S-SL	Upper, crest	HRT1,2,3; BKM 1,4,6
Moderate	Moderately well	26-50	SCL-L	Mid	MBN1,4; RBB1
High	Imperfectly to poorly	>50	Si-SiC CL-HC	Lower, toe	DON1,2,3; SIP1,2

Table 11–Seedling transplant mortality[1]

Hazard	Soil reaction (pH)	Water-holding capacity	Organic-layer thickness	Moisture regime	Soil map unit
			(cm)		
Low	4.0-6.5	High	<10	mesic to permesic	DON1; EOS1,2,3,4
Moderate	6.6-7.0	Medium	11-15	subhygric	COP1,3; LDG1,2,3,4
High	>7.0	Low	>15	hygric to hydric subxeric to xeric	HRT1,2,3,4; HTN 1 to 8

[1] See Dumanski et al. 1972. This table should be used with Table 10.

Planting Containerized Stock: In general, seedling survival and early growth is proportional to the volume available for root growth and development. Consequently, a seedling grown in a unit such as a Spencer-Lemaire 55-cc container will generally outperform those in the standard 40-cc container, particularly on sites with potential vegetation competition or snowshoe hare-damage problems.

Bare-Root Stock: Bare-root planting stock can generally gain an advantage over containerized stock. This is especially so on sites with abundant vegetational competition because of the greater size and age of the bare-root stock. This is more true with white spruce than with pine, due to the slow initial growth of the spruce.

C. Limitations to Reforestation Success

The limitations discussed here are those of the site and do not include management considerations such as planting errors which can be just as significant as site limitations (Froning 1972). The limitations are self-explanatory and mainly include considerations such as excess moisture, drought, steep slopes, and vegetational competition. High soil reaction (pH) is a problem on some soils of ecosystem associations in the Athabasca Valley near Hinton. These are not described in this report.

D. Frost-Heave Hazard

Frost-heave hazard is rated for the predominant soils of the ecosystem associations described on the basis of their likelihood of heaving tree seedlings upon freezing (table 10). This rating is based primarily upon the texture of the surface soil horizons and upon the moisture content of the soil, reflected by its drainage class. The most susceptible soils are those with fine-textured surface horizons with high silt content and imperfect drainage and where surface organic layers have been removed. Topographic situation can be an important determinant of frost-heave susceptibility with depressional situations being most susceptible.

Table 12–Factors affecting fire-hazard rating

Environmental factors	Forest stand and vegetation factors
moisture regime	tree species present
soil drainage	crown diameter and depth
topography	flammability of understory species
prevailing wind direction	size distribution of fuels
climate	abundance of fuels, bark thickness, rooting depth, organic-layer thickness, stand density, abundance of lichen growth

E. Seedling-Transplant Mortality

Potential mortality of planted seedlings has been rated on the basis of the most prevalent soil types occurring with each ecosystem association (table 11). The ratings were based largely upon early survival of very young transplants in unprepared, natural soils in the Hinton-Edson area (Dumanski et al. 1972). Ecosystem associations' soils are rated as high in terms of seedling mortality if they exhibit abnormally high soil reaction (pH), if they have low water-holding capacities, or if they have thick organic-surface horizons and are excessively wet during the growing season (Dumanski et al. 1972).

Productivity of the ecosystem associations.–Average values of gross, mean, annual, total volume increment (MAI), and site index (70 yr) are given for the dominant species of each ecosystem association. The values are from sample plots in natural, unmanaged stands. Site index is primarily estimated using the curves by MacLeod and Blyth (1955), although data for 137 plots in the Wapiti map area are from stem analysis (Corns 1978).

Fire hazard.–Fire hazard is inferred from knowledge of the flammability of the component species of the ecosystem types and from observed fire behavior in various forest types. These ratings were assigned for "cured dormant state" (early spring and late fall) and "active growth state" (late spring to early fall) for both "crownfires" and "surface fires" with the help of the fire-research unit of the Northern Forest Research Centre, Edmonton. The subjective ratings (table 12) will be greatly influenced by weather, topography, and by local fuel loading.

Table 13--Vegetational competition hazard

Hazard	Internal drainage	Texture B hor.	Elevation	Soil map unit
			(m)	
Low	Well to rapidly	S-SL	>1200	HRT1,2,3; BKM 1,4,6
Moderate	Moderately well	L-SCL	1000-1200	COP1,2,3; MLB4,6
High	Imperfectly to very poorly	CL-HC; Si-SiC	<1000	LDM1,2; SIP1,2,3

Table 14--Windthrow hazard

Hazard	Internal drainage	Organic layer thickness	Exposure to strong wind	Soil map unit
		(cm)		
Low	Rapid to well	<10	Slight	BKM1,4,6; COP1,3
Moderate	Moderately well to imperfect	11-20	Moderate	DON1; MBM3; NMP1
High	Poorly to very poorly	21-30	Severe	SIT: SIP1,2,3; SKY1,2

Table 15--Hare and rodent damage hazard on regenerating cutblocks

Hazard	Abundance of, low dense woody vegetation	Slash abundance	Elevation	Soil map unit
	(%)		(m)	
Low	0-20	Low	>1200	
Moderate	21-40	Moderate	1100-1200	
High	>40	High	<1100	

Vegetational competition.--Vegetational competition is rated according to type (predominant species or species groups) and severity, with respect to its influence upon young tree seedlings (table 13). Competition occurs for light, nutrients, water, and space.

Types of vegetational competition include that by reedgrass (primarily *Calamagrostis canadensis*), sedge (*Carex* spp.), ryegrass (*Elymus innovatus*), green alder (*Alnus crispa*), willow (*Salix* spp.), bracted honeysuckle (*Lonicera involucrata*), and forbs (especially those with large amounts of biomass and dense roots/rhizomes including *Mertensia paniculata, Aralia nudicaulis, Aster conspicuus,* and *Epilobium angustifolium*). Within the study area, *Calamagrostis canadensis* is the most serious competitor with conifer seedlings. It can form a dense sod that can influence soil-moisture and nutrient regimes and rooting abilities of tree seedlings. Seedlings can also be greatly shaded by the dense grass cover and they can be pushed down by the grass when it is laid down by heavy snow, wind, or rain. *Calamagrostis* is most abundant on moist, fine-textured soils over a wide elevational range and appears to be most prevalent in the eastern portions of the study area. The other species mentioned also seem to be most competitive on moist, fine-textured soils at lower elevations. Thus the occurrence of a particular ecosystem association on such soils would result in a high rating for vegetation competition.

Windthrow hazard.--Windthrow-hazard ratings reflect characteristics of the predominant soils occurring as part of the ecosystem associations described (table 14). These characteristics affect the development of tree roots and, therefore, the risk of trees being blown over by normal winds. These ratings, termed low, moderate, and high, are estimated from knowledge of root development under varying soil conditions and from field observations (Twardy and Corns 1980). It appears that trees are most subject to windthrow on soils having thick organic-surface horizons that are affected by high water tables, or on lithic soils having thin soil over consolidated bedrock. Windthrow is most often a problem on Organic and Gleysolic soils. When rating specific sites, however, exposure and occurrence of winds of high velocity should be considered as additional factors. It was not possible to consider these latter factors in the present general rating.

Rodent-damage hazard.--The potential for seedling browsing by snowshoe hares and rodents (table 15) is dependent upon the presence of suitable habitat. Preferred habitat for snowshoe hares, the species causing most damage, is low, dense, woody vegetation (Buehler and Keith 1982, Keith 1966) and heavy slash that provides cover from predators as well as food. In the study area, such habitat is most plentiful in the Aspen-White Spruce zone and Lower Boreal subzone at elevations below 1100 m, particularly on moist sites. The hare and rodent damage hazard is based upon the presence of dense, shrubby understories in the ecosystem associations described. The ratings are relative and are given for near peaks in the population cycle in years of very high hare abundance. Other species groups responsible for girdling damage to young conifers include squirrel, mouse, vole, and porcupine.

CONCLUSIONS

A forest-ecosystem classification framework, used in conjunction with reconnaissance soil-survey information, appears to provide complementary bases for making forest-management interpretations. The classification framework has the potential for providing a basis for additional interpretations related to forest management, hydrology, wildlife management, recreation, etc. as well as for research.

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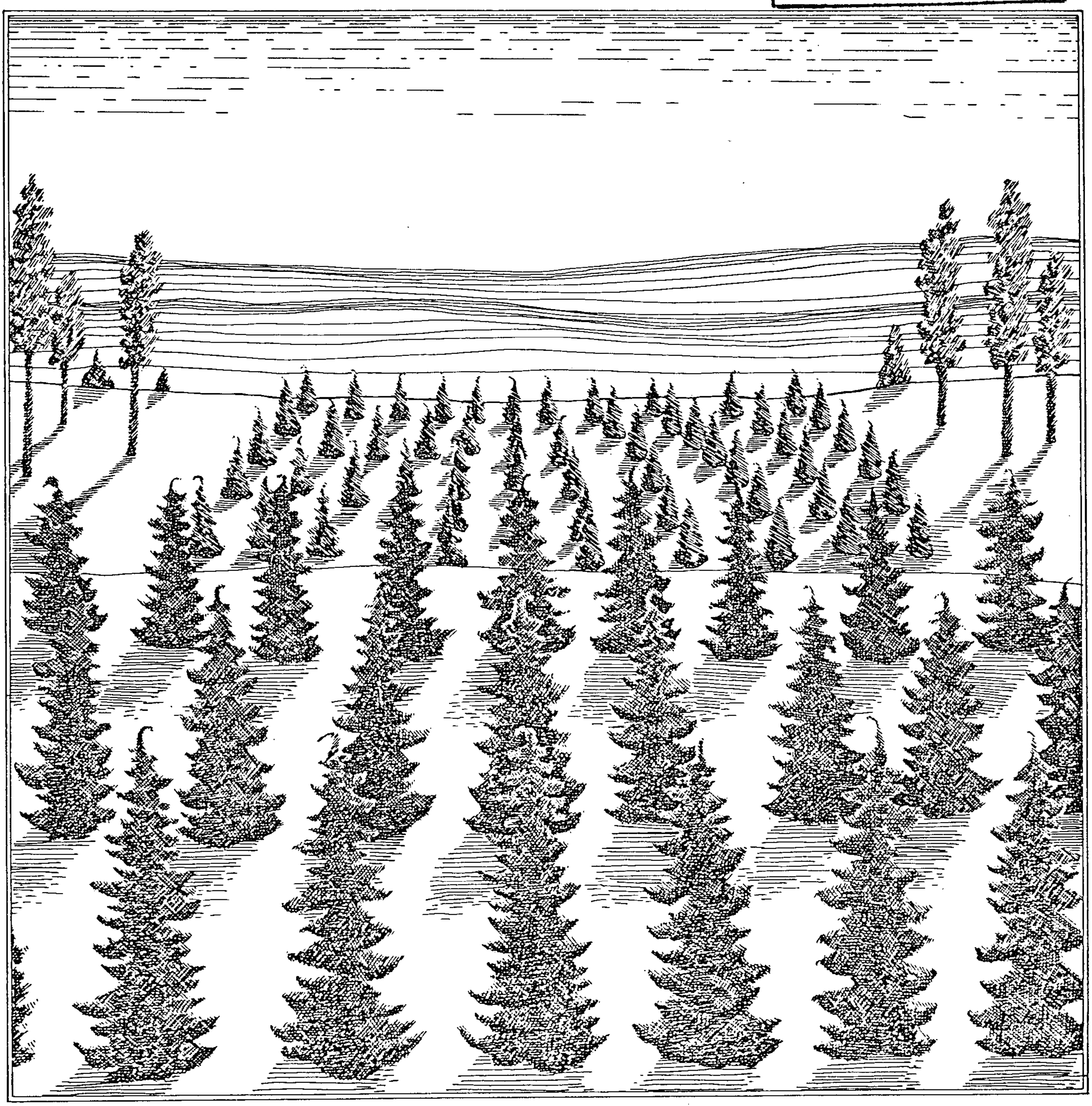

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Edited by

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