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ABSTRACT

The following situations presented difficulties in assessing forest stands in the Peace River District of British Columbia, according to C.L.I. survey techniques: (1) black spruce dominated dry sites and lodgepole pine dominated wet sites, the opposite of what was expected. Analysis of this problem indicated the anomalous tree pattern only represented seral stages following fire; (2) the height growth of young lodgepole pine varied widely on the same general soil type. Stocking density sufficient to cause early stagnation was considered to be the primary factor responsible for this problem.

INTRODUCTION

The Forestry Sector of the Canada Land Inventory conducted a survey in the Peace River District of northeastern British Columbia during the summer of 1970. The object was to assess the potential of the areas for wood fibre production, to determine species suitability and to define the limitations to growth inherent in the sites. During the survey, two situations were encountered that caused difficulties in assessing the areas. In one case, extensive growth of black spruce dominated dry sites while lodgepole pine dominated wet sites, a situation opposite to that generally occurring in physiographically similar areas within the same region. In the second instance, the height to age ratio of 18-year-old lodgepole pine stands varied widely on what appeared to be the same soil type. Analysis of aerial photographs and C.L.I. field techniques failed to disclose reasons for the anomalies.

These situations occurred within the Northern Foothills Section (19b) of the Boreal Forest Region, according to Rowe's (1959) description, and in the Boreal White and Black Spruce Zone of Krajina (1969). The climate is boreal with long, cold winters and short, often warm summers. At the Beatton River Airport, the nearest meteorological station, the mean annual daily temperature is 28 F (mean maximum 40 F and mean minimum 19.5 F) and frost can occur during any month of the year. The total annual precipitation is 16.6 inches (42 cm), with 9.34 inches (23.7 cm) as rain and the remainder as snow. June and July are the wet-test months and, along with August, the warmest. Marshall (1970) rated the area for agricultural climate capability as 5GF and 5F, indicating

1,200 to 1,650 degree days above 42 F.

The area lies to the south of the discontinuous permafrost zone (Brown, 1967) but within a section where patches of permafrost occur in bogs. Frost may penetrate to depths of 45 to 50 inches in mineral soils and deeper in organic soils (D.O.T. Frost Depth Indicator Readings, 1966-1967). The penetration is deepest when the soils are moist and the snow mantle is absent or thin during the time of freeze up.

In this section of the boreal region, black spruce (Picea mariana) is shade tolerant and exhibits the best growth on very moist to wet sites with low to moderate fertility; white spruce (Picea glauca) is generally shade intolerant and grows best on moist to wet sites of high fertility, and lodgepole pine (Pinus contorta var. latifolia) is shade intolerant and grows best on fresh to moist sites with moderate fertility (Krajina, 1969). Aspen (Populus tremuloides), eastern larch (Larix laricina) and white birch (Betula papyrifera) occur, usually in seral stages, but are of minor importance in most stands.

A special C.F.S. study was conducted to assist the C.L.I. personnel in assessing species suitability and productivity in the problem areas. The results of the investigation are reported here.

PROBLEM I

The first anomaly occurred near Holman Creek (57° 21' N. latitude and 122° W. longitude), northwest of Fort St. John, B. C. The pattern consisted of immature lodgepole pine as the dominant tree species on wet and moist sites on lower slopes and in valleys, and mature black spruce or mixtures of spruce and pine on fresh and dry sites on middle and upper slope positions. White spruce occurred sporadically on all but the wet sites; deciduous species, mostly aspen, were sparsely distributed on all sites. The arboreal understory layers consisted almost entirely of black spruce on all site types.

Methods

The terrain surrounding the area exhibiting the anomalous tree species distribution was examined on aerial photographs to select a control site. An accessible area with comparable landform and drainage patterns was selected approximately 20 miles from the problem area. Here, lodgepole pine dominated the drier sites and black spruce the wetter sites.

The soils of the region were classified and mapped by the B. C. Soil Survey (Farstad et al., 1965). For the current investigation, sufficient examination of soils in both study areas was conducted to establish their position in this classification scheme. Particular attention was given to texture, internal drainage and moisture regime of the soil at various positions on slopes.

Stand data such as density, height, age and species of trees were collected at several sites in both study areas by C.L.I. field crews. Use was made of these data for comparing tree species distribution in relation to site conditions. In addition, ground vegetation and arboreal reproduction were examined on several sites in each area. The depth and type of organic matter accumulation, including humus, litter and living moss, were noted for each site.

Results and Discussion

The stands in the area exhibiting the anomalous distribution characteristics were, in most cases, overstocked (700 to over 1,000 trees per acre) at ages ranging from 60 to over 120 years. The stocking density in the control zone was less, seldom over 500 trees per acre, and stand ages were mostly over 100 years. In both areas, the oldest trees often occurred on ridges, middle-aged trees on mid-slopes and the youngest trees on lower slopes and in valleys. The boundaries among the age groups were usually distinct.

The sites examined in both areas were located on gently sloping terrain in moisture shedding and receiving positions. The soils were derived from heavy-textured glacial till (loam to clay loam). The dry to moist upland soils were classified as the Alcan Series (Orthic Gray Luvisol) and the wet soils in depressions as the Buick Series (Low Humic Eluviated Gleysol) by Farstad et al. (1965). Both soils were slightly calcareous, somewhat saline, and low in nutrient status.

The surface mineral (A) horizon of the upland soils (Alcan Series) exhibited a higher degree of mottling in the problem area than in the control area, otherwise the soil profiles were essentially the same. The A horizon was about 7 inches thick and was underlain by a finer textured B horizon which impeded the downward percolation of water; however, water could move laterally down the slope through the A horizon. The mottling in soils of the problem area indicated that water was held in the A horizon for significant periods of time by something more than the B horizon, possibly a frozen layer.

A difference in the extent of frozen soil was apparent between the areas, which may account for the variation in mottling. In mid-June 1970, the soils on middle and lower slopes and in valleys and depressions were frozen to within 6 to 10 inches of the surface, in the area possessing the anomalous tree distribution. The soil above the frozen layer was saturated with moisture. In the control zone, frozen soils were found only in small patches under dense vegetation. The soil was generally wet but not saturated, except in association with frozen soil layers.

The vegetation characteristics could account for the frozen ground at that time of year. Dense stocking in the problem area resulted in nearly complete crown closure, which reduced insulation at ground level and evapotranspiration within the stand. These conditions were suitable for *Sphagnum* to inhabit mid-slope and valley positions. Very little snow could penetrate the canopy to form an insulating cover on the ground, allowing seasonal frost to accumulate. The *Sphagnum* ground cover would restrict heat penetration in the spring and delay thawing. These features were noted by Zoltai and Tarnocai (1971) under dense black spruce stands in Manitoba. In the control zone, the canopies were more open in most cases, allowing more snow to blanket the ground and greater penetration of insolation. The ground layer consisted of feathermosses (mostly *Hylocomium splendens* and *Pleurozium schreberi*) which do not restrict heat penetration as much as *Sphagnum*.

Black spruce has a greater tolerance to excessive moisture and frozen soil conditions than lodgepole pine or white spruce (Krajina, 1969). As stands develop, conditions become increasingly favorable for black spruce, and lodgepole pine is eliminated, usually after a normal rotation.

The lateral movement of water through the A horizon leaches minerals from the ridge tops and upper slope positions and deposits them in receiving areas, such as benches of less steeply sloping land in mid- and lower-slope positions or in valleys. The nutritionally poor sites on ridge tops and upper-slope positions would be favorable for growth of lodgepole pine and black spruce because of their low nutritional requirements. White spruce, which has a relatively high nutritional requirement, could favorably compete with other tree species in receiving areas of mid- and lower-slope positions. In the valleys, the nutrients may be deposited or carried out of the ecosystem by stream flow. However, even if the nutrients are deposited in valleys, the excessive soil moisture during the growing season is unsuitable for white spruce to grow well, and black spruce is favored.

The occurrence of distinct boundaries among stands of different ages indicated that fire was the factor responsible for their origin. The age distribution suggests that the more recent, and perhaps the most frequent fires occurred on lower slopes and in valleys but not on ridges in the problem area, the opposite of what Rowe (1970) found throughout the northwestern boreal region. This peculiar pattern could be due to wind being funneled through the valleys during fires. Observation of aerial photographs revealed this burn pattern to be prevalent in the area.

Fire is more advantageous to lodgepole pine than to black spruce. Both species have serotinous or semi-serotinous cones (Smithers, 1961; Wilton, 1963); however, lodgepole pine produces viable seed at a much earlier age (8 to 12 years) than black spruce (30 to 40 years). Therefore, if a second fire occurred in a burned area after a period of 15 to 30 years following the first fire, black spruce could essentially be eliminated, assuming complete burning. Lodgepole pine thrives under the open conditions produced by fires and even if black spruce regeneration occurs at the same time, lodgepole pine will overshadow it.

In summary, the anomalous forest cover patterns encountered by the C.L.I. field crews are not unique to the western section of the boreal forest; rather they represent seral stages following fires. Fire records were not maintained for this region until the last few decades. However, the presence of youngest stands occurring in valleys and middle-aged stands on slopes in the problem area gives evidence that fires may occur more frequently in the valleys. Regeneration following fires is often very dense, forming conditions favorable for cold soil temperatures and slow thawing in the spring. Black spruce is the only species that can thrive in such areas because of its tolerance to shade and frozen soil conditions. However, once established, lodgepole pine can persist for over 100 years. White spruce, because of its shade intolerance in this region, its high nutritional requirements (Krajina, 1969), its characteristic seed release within a few weeks after maturation (Sutton, 1969) and its infrequent seed production and low viability (Rowe, 1970), is a very poor competitor for space in this environment. The zone selected as a control presumably also represents seral stages but with a different fire pattern.

The fires reduced black spruce more on the ridges than in the valleys, a pattern perhaps more common to this section of the boreal forest. Both study areas had essentially only black spruce in the arboreal understory and this species could be the dominant "climax" species in the absence of fire. White spruce could only occupy nutritionally favorable sites either in pure stands or in association with black spruce. The valleys of the control area and the ridges of the problem area are currently close to the climax stage.

The dry, fresh and moist sites could be managed for merchantable lodgepole pine and white spruce, and a C.L.I. rating for these species would be justifiable on these sites since it is doubtful if merchantable black spruce could be grown. The wet sites should be rated for black spruce. Major limitations to forest growth potential are low temperature and excessive soil moisture.

PROBLEM II

In the vicinity of Milligan Creek (approximately 57° 10' N. latitude and 120° 30' W. longitude), north of Fort St. John, a situation existed over a large area where height growth of densely stocked 18-year-old lodgepole pine stands varied from less than 5 feet to over 21 feet. Where height growth was poorest, the trees were chlorotic, in contrast to the good color of taller trees. A gradient was noticeable in trees of intermediate height. No apparent reason for the variation in growth and stand condition could be determined either by aerial photograph interpretation or from C.L.I. field data.

The stands originated following a wild fire spread by gale force winds from logging slash into adjacent standing timber on 20 September 1950 (B. C. Forest Fire Records, unpublished).

Methods

Stands of trees representing the extremes and middle of the height gradient were selected for study. Tree age was measured by counting the growth rings of stems severed at ground level and by counting the internodes of standing trees. Tree height was measured with a tape. A qualitative assessment of the chlorotic condition and tree vigor was made. Residual snags were noted for species composition and tree growth of the forest cover preceding the fire. Soil profile characteristics were examined, mostly with reference to soil moisture regime. Soil samples were collected from six pits for laboratory analysis to determine if the nutrient status was responsible for the chlorosis and reduced height growth.

In the laboratory, the soil samples were air dried, crushed, passed through a 2 mm sieve, and subjected to the following physical and chemical analysis: texture by Bouyoucos hydrometer (Foth and Jacobs, 1959), 1/3 atmosphere moisture equivalent by centrifugation (Briggs and McLane, 1910), 15 atmospheres moisture retention by a pressure plate (U.S. Salinity Laboratory Staff, 1954), pH by glass electrode in 1:2.5 soil to water and soil to 0.01 M $CaCl_2$ mixtures, total nitrogen by

Kjeldahl, available phosphorus by the acid fluoride method (McMullan, 1971), total carbon by Leco induction furnace, iron and aluminum by oxalate and dithionite extractions, potassium, sodium, calcium and magnesium by atomic absorption after extraction with 1 N NH_4OAc, and hydrogen by $BaCl_2$/triethanolamine extraction (McMullan, 1972).

Results and Discussion

Physiographically, the area was gently rolling with extensive bogs in depressions and heavy-textured soils on the upland sites. The proportion of bog to upland soil was nearly equal. The soils were derived from heavy-textured lacustrine deposits (silty clay loam to silty clay) and were classified as the Milligan Soil Series (Orthic Gray Luvisol) by the B. C. Soil Survey (T. M. Lord, personal communication).

Logging records were not maintained, but it is assumed from existing snags and heavy wind-throw that the problem area occurred in the uncut portion of the burn. Dense lodgepole pine and black spruce became established following the fire, and little understory vegetation developed. Analysis of residual snags indicated the previous forest did not have the anomalous tree growth now apparent, but consisted of a fairly uniform stand of lodgepole pine and black spruce.

Soil nutrient and moisture characteristics were investigated because inadequacies in these factors may cause chlorosis and stunting of trees. There was no obvious relationship between topographic position or soil profile characteristics and the chlorotic trees. Mottling was observed at about 12 inches in depth in one profile possessing unhealthy trees and one possessing intermediate trees, but not in the others. Moisture retention at 15 atmospheres varied in proportion to clay content, but was inconsistent with respect to tree height and chlorosis (Table I). The moisture equivalent at 1/3 atmospheres had little relationship to any other soil parameter or to tree growth (Table I). These factors rule out the hypothesis that the soil water regime per se was the cause of variance in tree growth.

The Ca, Mg, K, Na, P and H contents and the C/N ratio varied among the sites (Table I), but the variation was not clearly consistent with tree growth differences. The Ca, Mg and Na contents were relatively high in one soil supporting healthy trees, but not in any others. The percent nitrogen indicated a slight relationship to tree growth, but was not of sufficient magnitude to account for the degree of variation. The C/N ratio was highest, due to a high percentage of carbon (Table I), in the surface of one soil supporting unhealthy trees, but the surface sample of the other soil supporting unhealthy trees was insufficient to perform a carbon determination. The soils were all extremely acid (Table I) and hydrogen was the most abundant exchangeable cation. The oxalate extractable Fe and Al and dithionite extractable Al (Table I) had little variation among or within the soils. The dithionite extractable Fe fluctuated, indicating a variation in amount of crystalline iron oxides (McKeague and Day, 1966), but had little correlation to tree growth. There is no clear-cut evidence to support the hypothesis that the soil nutrient status alone accounted for the variation in tree growth, although analyses of micro nutrients were not conducted.

The most plausible explanation for the variation in tree height and chlorosis observed is in stand density. Both black spruce and lodgepole pine produce serotinous cones, and conceivably seed from both species was abundant following the fire. The density of the subsequent regeneration was perhaps variable, due either to fire intensity in localized spots or to the occurrence of seed-bearing trees. Since the soils were generally low in fertility, densely stocked patches were likely to stagnate at an early age, as was evident from stem analyses. Stands of healthy trees had not as yet reached the point of stagnation.

The area is capable of producing reasonably good lodgepole pine with little management, and consequently a C.L.I. rating using this species as indicator would be justifiable. The major limitations to forest growth are cold temperatures and excess soil moisture. Lodgepole pine performs better than black and white spruce in soils low in nutrients (Swan, 1960), and has sufficient plasticity to allow growth on a wide range of soil moisture regimes (Krajina, 1969). In the absence of fire, black spruce would dominate the arboreal vegetation, but lodgepole pine would out-produce it for the first 80 to 100 years.

TABLE I. CHEMICAL AND PHYSICAL PROPERTIES OF THE SOILS UNDER 18-YEAR-OLD LODGEPOLE PINE

Ht of pine	Hor-izon	Depth (inches)	1/3 atm.	15 atm.	Texture sa:si:cl:	Texture class*	pH H_2O	pH $CaCl_2$	% C	% N	C/N ratio
21 ft	Ae	0-4	17.6	16.1	17:34:49	C	4.4	3.7	2.0	0.14	14.6
	AB	4-8	25.2	17.5	16:26:58	C	4.4	3.8	0.8	0.10	7.6
	B	8-20+	23.9	15.7	9:29:62	C	4.1	3.6	0.3	0.09	3.0
21 ft	Ae	0-3	23.2	6.9	8:60:32	SiCL	4.3	3.6	1.4	0.09	16.0
	AB	3-14	27.7	16.4	9:42:49	SiC	4.2	3.5	0.5	0.10	5.1
	Bn	14-24	21.6	12.8	7:49:44	SiC	3.9	3.4	0.2	0.07	3.0
	BC	24+	19.0	11.1	12:50:38	SiCL	3.5	3.2	0.2	0.08	2.8
14 ft	Ae	0-6	11.9	9.3	35:40:25	L	4.3	3.6	1.0	0.06	16.4
	AB	6-15	11.3	9.0	33:33:34	CL	3.9	3.5	0.2	0.06	3.6
	Bn	15-20	20.0	11.0	16:47:37	SiCL	3.9	3.6	0.3	0.07	4.2
	BC	20+	16.0	10.8	18:47:35	SiCL	3.9	3.4	0.3	0.08	3.8
13 ft	Ae	0-4	21.6	14.1	15:45:40	SiC	4.0	3.3	2.3	0.14	17.0
	AB	4-15	28.2	18.8	18:29:53	C	4.6	3.7	0.5	0.10	5.2
	B	15+	31.0	19.7	15:30:55	C	4.4	3.5	0.4	0.10	3.7
8 ft	Ae	0-3	--**	7.7	31:43:26	CL	4.3	3.6	--	0.10	--
	AB	3-12	18.0	8.0	35:36:29	CL	4.0	3.5	0.3	0.06	5.0
	Bn	12-22	10.3	8.3	25:40:35	CL	3.9	3.4	0.2	0.06	3.6
	BC	22+	14.6	6.5	27:45:28	CL	3.9	3.4	0.2	0.05	3.1
5 ft	Ae	0-3	--	11.0	34:36:30	CL	4.3	3.6	5.3	0.17	31.2
	AB	3-12	23.6	8.9	26:42:32	CL	3.9	3.5	0.5	0.07	7.5
	Bn	12-20+	20.0	7.8	28:43:29	CL	3.6	3.4	0.2	0.06	2.5

TABLE I - continued

Hor-izon	Exchangeable cations, meq/100 gm						Oxalate Ex.		Dithionate Ex.		P
	Ca	Mg	K	Na	H	C.E.C.	%Al	%Fe	% Al	% Fe	ppm
Ae	6.5	1.2	0.6	0.09	24.7	33.1	0.3	0.4	0.4	1.7	26.5
AB	6.4	1.3	0.4	0.09	18.7	26.9	0.4	0.4	0.3	1.9	3.6
B	7.4	1.7	0.3	0.12	22.3	31.7	0.3	0.2	0.3	2.8	2.5
Ae	2.1	0.6	0.3	0.04	18.3	21.2	0.2	0.1	0.1	0.7	38.2
AB	0.3	0.3	0.2	0.05	26.9	27.6	0.3	0.2	0.3	3.4	0.1
Bn	0.1	0.1	0.1	0.06	18.6	19.0	0.2	0.3	0.2	4.5	0.9
BC	0.1	0.1	0.2	0.05	19.0	19.4	0.1	0.3	0.2	2.5	0.7
Ae	0.3	0.0	0.3	0.04	23.0	23.6	0.2	0.4	0.2	1.0	16.5
AB	0.2	0.1	0.2	0.04	19.0	19.4	0.2	0.3	0.3	2.1	3.1
Bn	0.2	0.1	0.2	0.05	19.5	20.1	0.2	0.3	0.2	2.1	2.8
BC	0.2	0.1	0.2	0.06	15.3	15.9	0.1	0.3	0.1	1.9	1.7
Ae	0.9	0.4	0.4	0.09	27.1	28.9	0.3	0.3	0.2	1.8	30.7
AB	1.7	0.7	0.3	0.07	18.6	21.4	0.3	0.3	0.4	2.4	7.2
B	2.0	1.8	0.3	0.09	24.1	28.3	0.3	0.4	0.3	3.5	0.3
Ae	0.4	0.2	0.2	0.06	23.7	24.6	0.2	0.3	--	--	--
AB	0.2	0.1	0.2	0.04	18.3	18.9	0.2	0.3	0.2	1.9	4.8
Bn	0.1	0.1	0.2	0.06	18.0	18.5	0.2	0.3	0.2	1.9	2.1
BC	0.1	0.1	0.2	0.05	9.3	9.6	0.1	0.2	0.2	1.5	0.9
Ae	1.3	0.7	0.7	0.09	26.7	29.4	0.3	0.4	0.5	1.6	22.6
AB	0.3	0.1	0.2	0.07	19.9	20.6	0.1	0.3	0.2	1.7	7.8
Bn	0.3	0.1	0.2	0.04	13.6	14.2	0.1	0.4	0.1	2.0	7.6

* Texture classes: C -- clay, Si -- silt, CL -- clay loam, L -- loam.

** (--) sample quantity insufficient for determination.

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