FOREST-SOIL RELATIONSHIPS IN WESTERN ALBERTA AND RECONSTRUCTION OF FOREST SOILS IN RECLAMATION

By

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I GENERAL

Reclamation of disturbed land to a level of productivity equal or greater than what which existed prior to disturbance, requires a plan before industrial activity begins. The appropriate natural resource inventory will quantify the kinds and amounts of materials available to be managed and the ecological variations present before disturbance. It also provides information on the distribution of renewable resources and an insight into forest-soil relationships and the interpretations for future land use. The materials handling plan requires a decision on what product is appropriate after disturbance, the best suited vegetation and animal species, and how the maximum results can be obtained from the available materials and other resources. Once the desired product has been selected and the required substrate (soil, climate, ground-water) has been ascertained, then a suitable materials handling plan can be developed for removal and storage of overburden and substrate and the subsequent reshaping of the landscape to provide the desired product.

There are some useful reviews and summaries of the substrate requirements of trees (Pritchett 1979, Armson 1977), but there is still incomplete understanding of Alberta conditions and ecosystems. Some fundamental obersvations relative to lodegpole pine were made by Duffy (1964) and more recently for lodgepole pine and other species by Corns (1978).

II OBSERVED FOREST-SOIL RELATIONSHIPS IN BANFF AND JASPER

Observation of forest-soil relationships have occurred during the Banff-Jasper ecological inventory. The field work was completed in October 1979, and analyses and reporting are currently underway. Hence, this section reported some single factor relationships, using slides of Banff and Jasper. The air photos indicate that many of the observations made inside the Parks can be extended for considerable distances into the East Slopes.

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III FOREST-SOIL RELATIONSHIPS IN WESTERN ALBERTA (WAPITI SHEET)

In order to restore a forest site to a level of productivity equal or greater than that of the forest on the site prior to mining, it is necessary to have an appreciation of factors that may limit or control the potential forest productivity on that site for a particular tree species in question or conversely, given a particular set of site conditions such as reconstructed "soil", which tree species is best suited and most likely to achieve optimum productivity on that site?

A variety of approaches have been employed to estimate forest growth potential using direct or indirect methods (Rennie 1963, Ralston 1964, Jones 1969). Direct methods of site elevation usually involve establishment of permanent sample plots within mature forest stands and periodic remeasurement of the trees of the sample plot to subsequently calculate growth increments. Indirect methods for estimation of site productivity utilize a related attribute as a criterion. Four attribute groupings may be recognized: climate, ground vegetation, soil properties and foliar characteristics (Rennie, 1963).

This discussion will attempt to demonstrate which soil and site properties are important in determining forest productivity and in determining some common forest types in the western Alberta foothills area. The research reported here today was the basis for a Ph.D. dissertation by Corns (1978), and was conducted in conjunction with a reconnaissance soil survey of the Wapiti may area (Twardy and Corns in press).

The direct methods of assessing forest-soils relationships are discussed: 1) Stepwise multiple regression and 2) the forest vegetation type approach.

The multiple regression approach to forest growth prediction as discussed in this paper, was first tested statistically by Coile (1935) and is based upon empirical relations between site attributes and tree growth. Most studies using the multiple regression approach have used soil criteria as independent variables to predict a dependent variable, commonly site index. The conventional soil criteria include pH, available nutrients, moisture regime, texture and soil depth, although virtually any factor can be designated as an independent variable.

This paper considers abundance of understory species and other vegetation related attributes in one multivariate analysis method for prediction of tree growth, viz. stepwise multiple regression. The objective for the inclusion of percent ground cover of individual species and independent variables in addition to some conventional soil and site attributes is to increase the precision of estimates of growth parameters.

Study Area

Location - The study area is in western Alberta, within the Wapiti map area (National Topographic Series 83L) between 118° and 120°W longitude, and between 54° and 55°N latitude, covering an area of approximately 17,500 km^2. It is bordered to the west by the British Columbia boundary.

Surficial Geology and Soils - Both Cordilleran and Keewatin glacial ice covered parts of the study area. The influence of the Cordilleran ice is restricted to terrain that includes one-fourth to one-third of the map area in the south and west (Bayrock, 1972). 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 and recent alluvial deposits. A few small areas of shale, sandstone, coal and conglomerate outcrops are present in the more mountainous areas in the south western portion of the map sheet.

Soils of the Luvisolic, Brunisolic, Gleysolic, Regosolic, Podzolic, and Organic orders of the Canadian soil classification system (Canada Soil Survey Committee, Subcom. Soil Classification, 1978) are represented in the Wapiti map area. The dominant soil subgroups ranked in order of decreasing abundance are Orthic Gray Luvisols, Brunisolic Gray Luvisols, Gleyed Gray Luvisols, Podzolic Gray Luvisols and Orthic Eutric Brunisols.

Methods

1. Stepwise Multiple Regression

Plot areas were selected from Alberta Forest Service forest cover maps (1:126,720) and aerial photographs supplied by the Alberta Forest Service and Proctor and Gamble Cellulose Ltd. These plots encompassed a wide variety of vegetation, soil and landform types within uniform, even-aged and normally stocked stands, ranging from 45 to over 200 years old, with concentration within the modal age classes (70-80 years for the Wapiti map area). Sampling was primarily within the Upper Foothills (B.19c) and Lower Foothills (B.19a) Sections of the Boreal Forest Region (Rowe 1972) and to a much lesser extent in the East Slope Rockies Section (Sa.1) of the Subalpine Forest Region.

Within each sample plot, the soil profile at a representative location was examined and its morphology described according to procedures of the Canada Soil Survey Committee, Subcom. Soil Classification (1978).

Vegetation sampling was done on Circular 0.04 ha plots. Diameters and heights of all trees over 1 cm at breast height (140 cm) were tallied by species. When the tree tally was completed, five to seven healthy dominant and codominant trees, somewhat representative of diameter-height classes in the plot, were felled and sectioned at 0.3 m, 1.4 m and 1.8 or 3.7 m intervals upwards for stem analysis. Tree canopy cover was visually estimated at 12 random points in the centre of the quadrats used for analysis of subsidiary vegetation. Tree basal area was estimated with a Spiegel relaskop.

Tree growth parameters derived from stem data such as mean annual increment in total volume, were computed through the use of a stem analysis program (Pluth and Cameron, 1970). A simple FORTRAN program calculated total volume, merchantable volume, mean annual increment and basal area for the individual plots.

A stepwise multiple linear regression of the abbreviated Doolittle method (Steele and Torrie, 1960), was computed to relate the expression of forest productivity to soil, site and vegetation data collected from the stem analysis plots.

Options within the computer program allowed selection of the dependent and forced independent variables, and deletion of specific variables. If two variables were statistically intercorrelated or had similar known or inferred biological relationships to tree growth, one of the variables would be deleted from regression analysis. Prior to running the stepwise regression program, independent variables were plotted against the dependent variables using a bivariate plotting program. In cases of non-linear relationships, as apparent from an inspection of the bivariate plots, the appropriate linear or non-linear transformation was applied to the independent variable to best approximate a linear relationship. The criterion for the sequence of addition of the independent variables in the multiple regression was the magnitude of the given variables' contribution to R^2. In other words, the greater the contribution to R^2, the greater the correlation of that variable to variations in the dependent variable.

Regression equations presented for lodgepole pine (<u>Pinus contorta</u> var. <u>latifolia</u>) and white spruce (<u>Picea glauca</u>) give the dependent variable as a function of the nine independent variables accounting for the greatest proportion of R^2. The choice of nine independent variables is somewhat arbitrary.

2. Classification of the Forest Vegetation

Subsidiary vegetation, or the forest understory components, were sampled by visual estimates of percent cover by species within height strata. Cover of terrestrial bryophytes, herbs and dwarf shrub species (0.5 m tall) was estimated within 12 randomly-placed 1 x 1 m quadrats; that for shrub cover (0.5 m tall) in 5 x 5 m quadrats centred around the 1 x 1 m quadrats. Tree regeneration density was tallied by species and height class within the 5 x 5 m quadrats for individuals 1.5 m tall. Predominant plot aspects, slope angle, amount of deadfall and evidence of disease were also recorded.

The forest vegetation of the Wapiti map area was classified into 15 forest types on the basis of the dominant tree species, floristic composition and by environment as inferred from soils. The floristic classification was patterned after Braun-Blanquet's methods as described by Meuller-Dombois and Ellenberg (1974) and after a Bray and Curtis (1957) ordination. The concepts of the forest types were developed both during field investigations and after the plots were sampled and the data analyzed. No attempt was made to restrict sampling to certain forest types nor to exclude certain forest types from sampling, though certain forest types are not well represented, particularly those at high elevations.

Results and Discussion

1. Stepwise Multiple Regression

Variables entering the multiple regression equations can be classified as topographic, edaphic or vegetational (Tables 1 and 2). The proportion of the variation in the dependent variable, accounted for by an independent variable, depends upon the individual equation. The sequence for addition of the variables to the equations is according to their contribution to the R^2 value and is indicated in Tables 1 and 2.

Topographic variables used include elevation, slope angle and slope aspect. In general, productivity for lodgepole pine and white spruce is greater at lower elevation, a reflection of more favorable climate. Climate is usually the most important factor in determining forest productivity in Alberta. Both pine and spruce seem to prefer northerly aspects, and moderate slopes where favorable soil drainage is likely to occur.

Edaphic variables include horizon thicknesses, textures, products of thickness and texture, colors, consistence and structure. In addition, soil profile internal drainage is expressed through depth to mottles, drainage class and inferred hydraulic conductivity of the parent material. In general, the edaphic variables that appear to be important to pine and spruce productivity are those that indicate favorable soil moisture regime and conditions for good root penetrability. These factors and their relative importance can be determined from examination of Tables 1 and 2.

Vegetation related variables were introduced into the multiple regression equations in an attempt to increase the precision of the estimate of the dependent variable. The contribution of the vegetational variables to the precision of the regression is apparent (Tables 1 and 2). Independently calculated equations for lodgepole pine and white spruce mean annual increment in total volume (MAI) and site index (SI) at 70 years, indicates that a contribution of up to 0.42 (0.66 vs. 0.24) to the R^2 value in the case of lodgepole pine MAI (Table 1), can be accounted for by vegetation related independent variables. Vegetation-related variables contributed 0.33 to the R^2 value of the white spruce MAI and IS equations (0.86 vs. 0.53 and 0.91 vs. 0.58 respectively) and 0.22 to the R^2 value of the lodgepole pine site index equation (0.71 vs. 0.49).

Table 1 Coefficients of multiple linear regression equations for estimation of mean annual increment in total volume (MAI) and site index (SI) for lodgepole pine. Numbers in parentheses indicate the sequence for addition of the variable in the resepctive equations. Significance at probability levels:

* = .05, ** = .01

Independent Variables	With Vegetation MAI	Variables SI	Without Vegetation MAI	Variables SI
Constant	-14.3	252.5	76.0	343.3
Topographic				
Elevation (m)			-0.00424(3)	-81.6**(1)
Log elevation		-54.7**(1)		
Slope angle (%)				0.217(3)
Slope aspect	38.3*(8)		3.12(5)	
Edaphic				
Thickness Organic Horizon (cm)			-2.18(6)	
Thickness A Horiz. X%(Si+C)			-0.0125(2)	-0.0071(5)
Chroma A Horizon			3.90*(1)	1.55(2)
% Clay A Horizon				
% Clay B Horizon				5.44(7)
Consistence B Horizon	-7.29**(6)	-4.48**(8)		
Value B Horizon	-4.28*(9)	-0.332(9)		
Structure B Horizon			-3.65(4)	
Hue B Horizon				-0.519(4)
Depth to Mottles (cm)	-0.431**(5)			
Drainage class		-4.07**(7)		
Hydraulic Conductivity (cm hr^{-1})				-0.0138*(6)

Independent Variables	With Vegetation MAI	Variables SI	Without Vegetation MAI	Variables SI
Vegetational				
1/log litter cover (%)	-29.6**(1)	-11.9**(2)		
Canopy Cover (%)	0.429**(2)			
Deadfall Cover (%)	0.561**(3)			
Lichen Cover (%)	-1.12**(4)	-0.725**(3)		
Cornus canadensis (%)	0.687**(7)	0.385**(6)		
Rubus pubescens (%)		2.11*(4)		
Regeneration density (stems/ha)		.00406**(5)		
R^2	0.66	0.71	0.24	0.49

Table 2 Coefficients of multiple linear regression equations for estimation of mean annual increment in total volume (MAI) and site index (SI) for white spruce. Numbers in parentheses indicate the sequence for addition of the variable in the respective equations. Significance at probability level: * = .05, ** = .01.

Independent Variables	With Vegetation MAI	Variables SI	Without Vegetation MAI	Variables SI
Constant	2.67	21.1	3.81	15.70
Topographic				
Elevation(m)	-0.007**(4)	-0.004**(1)	-0.008**(2)	-0.004**(1)
Slope angle (%)			1.847*(4)	0.754*(5)
Slope aspect	12.88**(8)	0.918(4)		
Edaphic				
Log thickness organic horiz.			17.74(6)	
Hue B Horizon		0.584(9)	4.977**(3)	1.413(6)
Value B Horizon			9.491(5)	5.191(3)
Chroma - B Horizon				-1.785(7)
Drainage Class		2.320*(5)		
Log hydraulic conductivity (cm hr^{-1})	3.32(1)		12.43**(1)	-3.900*(4)
Stone volume (%)	0.362*(9)			
Vegetational				
1/log litter cover		9.673*(8)		
Canopy cover (%)	1.33**(2)			
Deadfall cover (%)		-1.110**(2)		

Independent Variables	With Vegetation MAI	Variables SI	Without Vegetation MAI	Variables SI
Ledum groenlandicum cover (%)	-5.43**(3)	-1.638**(3)		
Rosa acicularis cover (%)	-9.08**(5)	-1.972*(7)		
Calamagrostis canadensis cover (%)	-47.0**(6)			
Cornus canadensis cover (%)		0.769**(6)		
Regeneration density (stems/ha)	0.03**			
R^2	.86	.91	.53	.58

The Vegetation Variables

Most of the vegetation-related variables used in the regression were expressed as percent cover of individual plant species. Litter, forest canopy, deadfall, total lichen, total moss and total vascular plant cover values were also used. In addition, total tree regeneration was expressed as stems ha^{-1}. Many of the vegetation related variables are likely indicators of soil moisture regime and climate, but the factors controlling the occurrence and abundance of other vegetation related variables are less apparent. It appears that some plant species or other vegetation related variables are better indicators of conditions favorable to tree growth than the soil physical properties used. Of course, one should remember that understory plant distribution is a function of environmental factors in the same manner as is tree growth.

2. Classification of Forest Vegetation

Some relationships between forest vegetation type, productivity and soils are illustrated with the following and examples from Corns (1978). In this section, comments are made where applicable, pertaining to handling during reclamation of the soil material described. An integrated resource inventory, in addition to quantifying the soils and vegetation (and wildlife) resources, can also yield information valuable in determining forest soils relationships that may be very important to consider when reconstructing a forest soil after mining.

1. White spruce/Trailing dewberry - Two leaved Solomon's seal (Picea glauca/Rubus pubescens--Maianthemum canadense).

These white spruce forests occur at low to medium elevations (670 to 1220 m) on generally north-sloping (CSSC slope classes 1 to 6) sites. They are generally young (70 to 140 years) and have well developed shrub and herb understorys. Characteristic species are Lonicera involucrata, Rosa acicularis, Viburnum edule, Rubus pubescens, Maianthemum canadense, Mitella nuda, Cornus canadensis, Linnaea borealis and Petasites palmatus. Cornus stolonifera, Alnus crispa, Alnus tenuifolia and Aralia nudicaulis are often evident in this type, but are seldom seen on the other white spruce types. Hylocomium splendens is the predominant moss. This type can commonly be seen on depressional sites within aspen forest, suggesting that succession advances faster on these sites. The abundance of white and black spruce seedlings and fir seedlings in some stands of this type should ensure perpetuation of this type as well as increased abundance of black spruce and subalpine fir in some stands. Forestry productivity is good (CLI classes 3 and 4 with some examples of site class 2), but appears to be less in the older forests. It is distinguished from the wetter Picea glauca/Equisetum arvense/Hylocomium splendens type by the presence of Maianthemum canadense, lower Equisetum arvense cover, the absence of Carex capillaris, less moss cover and by generally better drained soils.

Soils are moderately well to imperfectly drained Orthic Gray Luvisols, Gleyed Gray Luvisols and Luvic Gleysols on alluvium over lacustro-till, Continental and Cordilleran till. Donnelly, Snipe and Edson are the predominant soil groups. The extensive gullying demonstrates the handling problems that occur with very fine textured materials like those of lacustrine deposits.

2. White spruce/Horsetail/Feathermoss (Picea glauca/Equisetum arvense/Hylocomium splendens).

The white spruce-horsetail forests occur at low to moderately high elevations (670 to 1450 m) on gentle (classes 1 to 4), generally northfacing slopes. They are young to moderately old (80 to 220 years). White spruce and subalpine fir regeneration is common in many of the stands. The understory is herb dominated and a dense Hylocomium splendens cover is present, with lesser amounts of Ptilium crista-castrensis and Pleurozium schreberi. Constant species include Rosa acicularis, Lonicera involucrata, Equisetum arvense, Petasites palmatus, Mertensia paniculata, Mitella nuda, Cornus canadensis, Linnaea borealis and Rubus pubescens. Carex capillaris, an indicator of the moist conditions of this type, is found in approximately one-half of the plots of this type. Forest productivity is variable (class 2 to 5) and appears to be less in the older forests.

Soils are poorly to imperfectly drained peaty Orthic Gleysols, peaty Luvic Gleysols and Orthic, Luvic and Rego Gleysols on Continental till, alluvial and lacustrotill parent materials. Snipe, Smoky and Gunderson are the predominant soil groups. Tree rooting is shallow on these soils, which are difficult to handle when wet.

3. Black spruce/Labrador tea/Cloud berry
(Picea mariana/Ledum groenlandicum/Rubus Chamaemorus)

This type represents the black spruce bog forest vegetation. The bogs occur at low to mid-elevations (915 to 1070 m) in depressions with impeded drainage on level sites, with hummocky microtopography. These open forests are often over 200 years old and can be considered climax. The well developed shrub layer is dominated by Ledum groenlandicum. The herb-dwarf shrub understory is dominated by Vaccinium vitis-idaea, Rubus chamaemorus and Oxycoccus microcarpus. Sphagnum spp. are abundant. Tree cover is sparse and productivity is very low (class 7) and can be considered non-merchantable.

Soils are poorly drained Typic Mesisols and Fibrisols on moss peat parent materials and trees are shallow rooted. Kenzie is the predominant soil unit. Slide 7 illustrates a poorly drained Fibrisol, an organic parent material derived from Sphagnum moss. This material could provide a valuable source of organic matter for reconstruction on mineral soils. Peat depth on these soils may range from less than 1 to over 10 meters.

4. Lodgepole pine/Black spruce/Labrador tea/Tall bilbery
(Pinus contorta/Picea mariana/Ledum groenlandicum/
Vaccinium membranaceum).

The lodgepole pine-black spruce-Labrador tea-Tall bilbery forest type is more extensive than any of the others in the 83L area, and occurs on gently sloping (classes 1 to 5) sites of variable aspect from low to relatively high elevations (840-1465 m). It is characterized by young to fairly old (65-190 years) lodgepole pine and black spruce stands of fire origin. Black spruce forms a tree understory layer of approximately the same age as the pine. Black spruce and subalpine fir regeneration is often abundant, indicating probably eventual succession to these species. Ledum often forms a dense low shrub understory, and herb cover is moderate. Constant species include Ledum groenlandicum, Vaccinium membranaceum, Vaccinium vitis-idaea, Cornus canadensis and Linnaea borealis. A dense feathermoss cover of Pleurozium schreberi and Hylocomium splendens is usual. At the upper limits of type 4, Rubus pedatus is common, and Menziesia glabella, Rhododendron albiflorum, Tiarella trifoliata, and Arnica latifolia are sporadic in occurrence. Forest productivity is moderate (class 5 with a few exceptions).

Soils are moderately well to imperfectly drained orthic Gray Luvisols, Brunisolic Gray Luvisols and "bleached" Gray Luvisols. Edson, Mayberne and Marlboro are the predominant soil units. A moderately well drained Othic Gray Luvisol on clay loam textured moderately calcareous continental till on rolling topography (Edson soil group), is very common in the Alberta lower foothills and would be very susceptible to compaction during soil reconstruction.

5. Picea engelmannii-Abies lasiocarpa/Menziesia glabella

The Englemann spruce-subalpine fir-false azalea forests form a climax type, which occurs on steep (classes 5 to 7) north-facing slopes, at high elevations (above 1670 m) in the south west corner of the Wapiti map area. Menziesia may form a fairly dense shrub understory, but herb and low shrub cover is generally sparse. Constant species include Menziesia glabella, Phyllodoce empetriformis, Vaccinium membranacium, Rubus pedatus, Pedicularis bracteosa, Cornus canadensis, Lycopodium annotinum and Arnica latifolia. Tree growth is slow (CLI classes 5 and 6) and stands are usually not suitable for commercial use. The type is species poor and would show a slow recovery after disturbance. Soils are moderately well to imperfectly drained Orthic Gray Luvisols on Cordilleran till. Robb and Copton are the predominant soil groups. Slide 11 illustrates a Brunisolic Gray Luvisol on loam textured non-calcareous Cordilleran till parent material, on rolling topography. This soil (Robb soil group) is very widespread in the Alberta foothills and would be expected to have more favorable handling characteristics than the Edson soil.

Summary

An integrated resource inventory is an effective, efficient means of quantifying soil and vegetation resources and can also provide relationships between (forest) vegetation and soils that may be useful in reconstructing a forest soil environment. A quantitative model of forest growth as a function of the factors that control it should be a useful tool for gaining an appreciation of forest-soils relationships. Such knowledge is prerequisite to a forest-soils reconstruction program.

RECONSTRUCTION OF FOREST SOILS IN RECLAMATION

Review

A. Banff-Jasper Project

Specific benefits of a resource inventory like Banff-Jasper are that it provides information on the kinds of soil and vegetation encountered and their distribution. It also provides an insight into the ecology of the area.

1. The wide range of surficial materials and soils combine with other widely varying environmental components such as climate, topography, aspect, elevation, etc. so that no single factor controls forest growth. Inter-relationships occur among: moisture regime, drainage, soil texure, pH, topography, aspect, elevation, temperature, soil compaction, geologic materials, climate, tree dominance, vegetation type and kind and intensity of use (e.g. grazing, recreation, fire control). The combined result of all of these inter-relationships is that other factors besides soil depth are important in controlling forest and other vegetation growth.

2. There is a problem of relating data to productivity and prediction; that is, what is the relevance of rooting depth to reconstructed soils?

b. Wapiti Sheet

1. Lodgepole pine and white spruce seem to prefer northerly aspects and moderate slopes, where favorable soil drainage is likely to occur.

2. Lodgepole pine and white spruce productivity is largely determined by climate and soil physical properties that determine favorable soil moisture regime and root penetrability.

3. Vegetation-related independent variables account for large amounts of the variability in lodgepole pine and white spruce mean annual increment and site index.

4. A quantitative model of forest growth is a useful tool to develop understanding of forest-soil relationships.

REFERENCES CITED

1. Armson, K.A. 1977. Forest soils: Properties and Processes. University of Toronto Press. 390 pp.

2. Bayrock L.A. 1972. Surficial geology of the Wapiti map area. Alberta Research Council. Unpublished map.

3. Bray, J.R. and J.T. Curtis. 1957. As ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27: 325-349.

4. Canada Soil Survey Committee. 1978. The Canadian system of soil classification. Agriculture Canada Research Branch. Publ. No. 1646.

5. Coile, T.C. 1935. Relation of site index for shortleaf pine to certain physical properties of the soil. J. Forest. 33: 726-730.

6. Corns, I.G.W. 1978. Tree growth prediction and plant community distribution in relation to environmental factors in lodgepole pine, white spruce, black spruce and aspen forests of western Alberta foothills. Unpubl. Ph.D. thesis. Department of Soil Science, University of Alberta. 229 pp.

7. Duffy, P.J.B. 1964. Relationships between site factors and growth of lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.) in the foothills section of Alberta. Canadian Dept. For. Publ. No. 1065.

8. Jones, J.R. 1969. Review and comparison of site evaluation methods. U.S.D.A. Res. Pap. Rm. 51. Rocky Mountain For. and Range Expt. Sta., Fort Collins, Colorado.

9. Minore, D., C.E. Smith and R.F. Woolard. 1969. Effects of high soil density on seedling root growth of several north western tree species. U.S.D.A. Forest Service Reserach Note, Pacific North West Forest and Range Experiment Station.

10. Mueller, Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons. Toronto. 574 p.

11. Pluth, D.J. and D.R. Cameron. 1971. Fortran IV programs for computing and graphing tree growth parameters from stem analysis. For. Sci. 17:103.

12. Pritchett, W.L. 1979. Properties and management of Forest Soils. John Wiley and Sons. 500 p.

13. Ralston, C.W. 1964. Evaluation of Forest Site Productivity. Int. Rev. For. Res. 1:171-201.

14. Rennie, P.J. 1963. Methods of assessing forest site capacity. Canadian Dept. For. Res. Br. Contr. No. 543. Reprinted from Commonwealth For. Rev. 42(4), No. 114.

15. Rowe, J.S. 1972. Forest Regions of Canada. Can. Dept. Env. Can. For. Serv. Publ. No. 1300.

16. Steel, R.G.D. and J.H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, Toronto. 481 p.

17. Twardy, A.G. and I.G.W. Corns (in print). Soil Survey and Interpretations of the Wapiti map area (83L) Alta; Alberta Soil Survey Report No. 39. Alberta Research Council.

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