FOREST RESEARCH REPORT

NOVA SCOTIA DEPARTMENT OF LANDS AND FORESTS
P.O. BOX 68, TRURO, N.S. B2N 5B8

No. 24, March 1990

NORWAY SPRUCE: GROWTH POTENTIAL FOR NOVA SCOTIA

INTRODUCTION

Background

Norway spruce *(Picea abies* (L.) Karst.) is a wide-ranging species that is native from southern France and Yugoslavia to northern Scandinavia and from central Europe to Russia. From a quality and quantity standpoint, this conifer is the most important species in Europe. Norway spruce is planted extensively outside its natural range and was one of the first non-native species introduced to North America. According to Fowler and Coles (1979) this species has been the most widely planted exotic in eastern North America.

In Nova Scotia, one of the oldest Norway spruce plantations, excluding windbreaks and ornamental plantings, can be found at Lorne, Pictou County where Gordon MacKay planted approximately 2 acres in 1934. Mr. MacKay continued planting other native and exotic species and his plantations are recognized as some of the best examples of plantation forestry in the Maritimes. Earlier, in 1925 at Upper Sixty Lake, Kings County, a direct seeding of Norway spruce was carried out on 27 acres of burned-over land.

Prior to 1971, only 850 acres of Norway spruce had been planted in Nova Scotia. However, since then, the number of seedlings planted has increased. In fact, since 1980, almost 10 million seedlings have been planted on an estimated 3300 hectares.

The growth of Norway spruce in eastern North America has generally been reported as superior to that of native spruces on comparable sites (Fowler and Coles, 1979). Fowler (1984) states that provenance trials in the Maritimes have shown that Norway spruce is capable of out-producing native species when planted on appropriate sites. Bailey (1973), reporting on the growth of superior stands in Nova Scotia, found that the best plantations of Norway spruce were clearly more productive than the best comparable plantations or stands of native spruces. An

FUNDED UNDER CANADA/NOVA SCOTIA FOREST RESOURCE DEVELOPMENT AGREEMENT

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early planting in 1918 at Fownes Head, New Brunswick showed exceptional growth and development with a mean annual increment of 15 $m^3/(ha \cdot a)$ (Hughes and Loucks, 1962). Also in New Brunswick, a 30 year old plantation at Sunnyside Beach, Queens County, was growing at 9.5 $m^3/(ha \cdot a)$ (West, 1984). Growth and yield statistics from permanent sample plots in Nova Scotia have documented yields varying from 8.6 - 13.1 $m^3/(ha \cdot a)$ for Norway spruce stands ranging in age from 27 to 47 years.

Silvics

In North America, Norway spruce attains its best growth on moist, cool, acid sites in the temperate climate of the eastern United States and eastern Canada (Holst and Heimburger, 1969). A review of European and North American literature by Haines (1974) determined that the best growth of Norway spruce occurred on medium textured, fresh to moist loam and sandy loam soils. In addition, Norway spruce requires a high atmospheric moisture content which explains why this species performs so well in moist and rainy climates. Because of its shallow root system, Norway spruce requires a high degree of soil moisture, especially in the upper horizons. The shallower the soil, the higher the soil moisture needed for good growth. Haines' review also revealed that Norway spruce is shade tolerant in its youth but becomes more light demanding as it grows older. Furthermore, Norway spruce does not place a high demand on the soil for minerals. In fact, no correlation was found between growth and various soil parameters for Norway spruce plantations located in the Great Lakes-St. Lawrence River forest region (MacArthur, 1964) (i.e. phosphorous, calcium, potassium, iron, manganese, sodium, soil texture, organic matter, pH, C/N ratio, degree of base saturation or exchange capacity). Norway spruce tolerates a wide range of nutrient regimes and can be called humble in its nutritional demands.

Damaging Agents

Norway spruce is more susceptible to damage by the white pine weevil *(Pissodes strobi* Peck) than are the native spruces (Fowler and Coles, 1979). However, the authors also state that weevil damage is quite variable. As a result, some trees exhibited a pronounced crook while others did not.

Fowler and Coles (1979) report that frost and winter drying affect height growth and the overall health of the tree. Late frosts in the spring have the potential to do more damage than early fall frosts. Winter drying on exposed sites may cause foliage loss but most buds survive with minimal effect on height growth. Once the stand has closed, winter drying occurs only on exposed edge trees.

Observations by Fowler and Coles (1979) indicate that Norway spruce is highly susceptible to damage by the spruce budworm *(Choristoneura fumiferana* Clemens). They rate it in the same category as red spruce *(Picea rubens* Sarg.) and somewhat more susceptible to serious damage than white spruce *(Picea glauca* (Moench) Voss). However, because Norway spruce has an early bud flush, the budworm larvae become exposed at an early stage in their development. Therefore they can be controlled by foliar applications of biological and/or chemical pesticides before causing extensive damage.

Agents capable of causing damage to young Norway spruce by debudding include the red squirrel and pine grosbeak. The porcupine is conceded to be a serious enemy of Norway spruce although the tree does not appear to be the preferred species. Damage, however, can be extensive in areas of high population or close proximity to dens.

METHODS

To better define the increase in yields which can be expected by planting Norway spruce, a preliminary survey of 23 plantations throughout Nova Scotia was undertaken in the fall of 1989 (Figure 1). Plantations sampled were free growing, well stocked, free from major pest damage and located adjacent to natural stands or plantations of native species on similar sites. At each location, a description including the soil profile, vegetation and topography was completed. Five dominant trees were selected for measurement within an area roughly equivalent to 1/10th acre. Annual height increments were measured with the aid of a telescopic, digital reading, measuring pole extending to a height of 8 metres. Tree height, diameter at breast height, and age at stump and breast height were recorded. Plantations and natural stands of native conifers on the same site and adjacent to the Norway spruce were also measured.

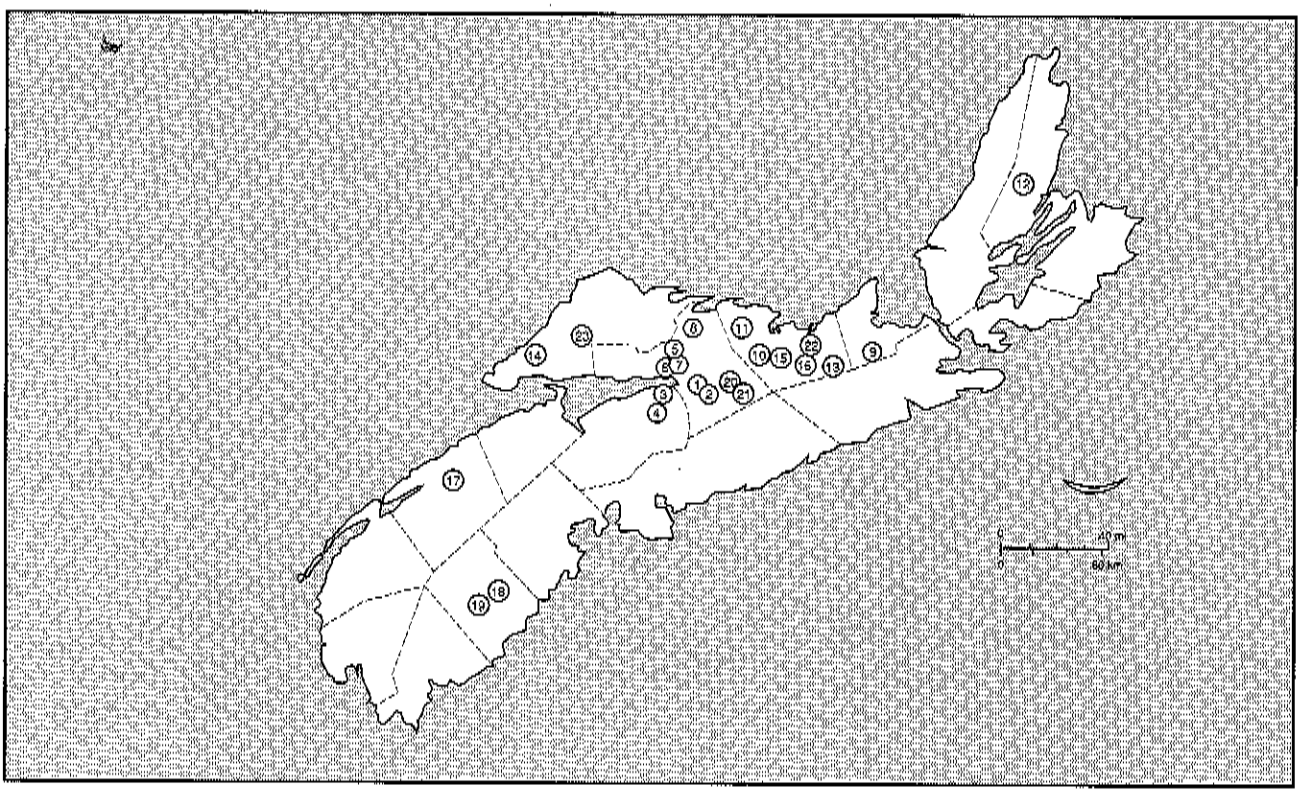

Figure 1. Location of the sampled Norway spruce plantations.

RESULTS AND DISCUSSION

Of the 23 Norway spruce plantations sampled, 14 were less than 20 years old (Appendix I). The oldest plantation measured was planted in 1933. Adjacent natural stands and plantations selected for growth comparison included red spruce (5), white spruce (11), red pine *(Pinus resinosa* Ait.) (10), and black spruce *(Picea mariana* (Mill.) B.S.P.) (5).

Site History

Site history appears to play an important role in the growth performance of Norway spruce. For example, the 9 Norway spruce plantations established on abandoned agricultural lands (Table 1) required, on average, 9 years to attain breast height. Seven out of the 9 old fields were site prepared but none were weeded. For comparison purposes, the 12 Norway spruce planta-

tions located on cutovers took only 5 years to reach breast height. All of the cutover sites were site prepared and 5 were weeded.

Only one plantation was assessed where Norway spruce had been established on an ericaceous site. This plantation, located on a gravelly esker along the Boar's Back Road in Cumberland County, was established in 1944. In those parts of the plantation where alternate rows of Norway spruce and red pine were planted, the red pine quickly overtopped the spruce so that today only a few spruce have survived. The spruce that did survive are still severely suppressed and do not form part of the main canopy. However, in other parts of the plantation, where Norway spruce and red pine were established in pure stands, the spruce plantations are performing better than the red pine. This is despite the fact it took 14 years to reach breast height for the Norway spruce compared to 6 years for the adjacent red pine (Table 2). As a result of its faster height growth above breast height, the land capability (LC) for the Norway spruce based on breast height age is 9.6 $m^3/(ha \cdot a)$ compared to 8.6 $m^3/(ha \cdot a)$ for the red pine. The difference in ages to breast height is attributed to differences in rooting habits. Norway spruce has a lateral root system and therefore competes directly with the root systems of the ericaceous vegetation. This competition continues until the shade from the expanding crowns reaches a level where the ericaceous vegetation can no longer survive. Red pine, on the other hand, is capable of sending down a taproot to access moisture and nutrients below the ericaceous root mat, hence its faster initial height growth.

Table 1. Years to reach breast height in relation to site history.

Softwood Cutovers						Old Fields					
Location	SA	BHA	YTBH	SP	WD	Location	SA	BHA	YTBH	SP	WD
Glenco	8	5	3	BR	Nil	Six Mile Bk.	17	8	9	SFP	Nil
E. Folly Mtn.	9	4	5	RD	Yes	Lovat	17	7	10	SFP	Nil
E. Folly Mtn.	9	5	4	HH	Nil	Kirkmount	20	13	7	SFP	Nil
Donny Brook	9	5	4	BR	Yes	Harmony	20	13	7	Nil	Nil
Greenfield #1	11	6	5	RD	Nil	Berichan	23	13	10	SFP	Nil
Greenfield #2	11	6	5	RD	Nil	Dryden Lake	32	24	8	SFP	Nil
Red River Road	11	7	4	RD	Nil	Lawrencetown	49	37	12	SFP	Nil
Upper Debert	12	7	5	RD	Nil	Lorne	56	48	8	SFP	Nil
Georgefield	12	7	5	RD	Yes	Caledonia	57	47	10	Nil	Nil
Otterbrook #20	14	9	5	SF	Yes						
Otterbrook #21	14	9	5	SF	Yes						
Kelly Road	19	10	9	FP	Nil						
Average	12	7	5			Average	32	23	9		

SA = stump age
BHA = age at breast height (1.35m)
YTBH = years to reach breast height for dominant trees
WD = Nil - no weeding
Yes - chemical weeding

SP = site preparation
SFP - single furrow plow
RD - rome disc
HH - Hahn harvester
BR - brush rake
SF - shark fin barrels
FP - Finnish plow

Table 2. Growth of Norway spruce (NS) and red pine (rP) on an ericaceous site - Boar's Back Road

	SA	BHA	YTBH	Height (m)	MAIHT(SA) (cm)	MAIHT(BHA) (cm)	LC(BHA) (m^3/(ha•a))	SP	WD
NS	46	32	14	16.7	36	48	9.6	Nil	Nil
rP	45	39	6	18.1	40	43	8.6	Nil	Nil

SA = stump age
BHA = breast height age (1.35m)
Height = average height of the 5 tallest trees
MAIHT(SA) = mean annual height increment based on stump age
MAIHT(BHA) = mean annual height increment based on breast height age
LC(BHA) = land capability based on breast height age
SP = site preparation
WD = nil - no weeding
YTBH = years to breast height for dominant trees

Height Growth

At 21 of the 23 locations, Norway spruce performed better than the native conifers. At the other 2 locations, young plantations of Norway spruce compared equally with the growth of the native species (Appendix I). Based on all sites, average mean annual height increment (above breast height) was 59 cm (23 inches) per year compared to 42 cm (17 inches) for the native species—a 40% increase.

Potential Yields

To obtain an estimate of the difference in yields between Norway spruce and native species at or near rotation age, the 9 plantations over 20 years of age were selected for comparison (Table 3). Estimated potential yields cited in this report are based on height-breast height age-mean annual increment (MAI) curves developed by the Nova Scotia Department of Lands and Forests (unpublished data). In every instance, the LC for Norway spruce was greater than that for the native softwood species located on adjacent similar sites. The difference ranged from 1.0 - 7.8 m^3/(ha•a) and averaged 3.8 m^3/(ha•a) (0.68 cords/acre/year), an increase of nearly 58% (Table 3). This means that over a 40 year rotation, Norway spruce could outproduce our native species by 152 m^3/ha or 27 cords/acre. On 2 sites Norway spruce did not greatly outperform the native species (Boar's Back Road and Caledonia). The poor growth is attributed to shallow and hence dry soil (35 cm to bedrock) at Caledonia and to the ericaceous cover at the Boar's Back Road site as previously discussed. While the yields from these stands (9.6 and 7.4 m^3/(ha•a)) can be considered poor relative to other Norway spruce stands, they are not poor relative to the average potential for native softwoods in Nova Scotia (5.6 m^3/(ha•a) (unpubl. data, N.S. Dept. of Lands & Forests).

Traditionally in Nova Scotia, LC has been determined from height-age-MAI curves based on stump age. However, these curves are only accurate if the dominant trees have been free to grow for their entire life. Since this was not the case for old fields and barrens as previously discussed, LC based on stump age provides a much lower estimate of LC than that based on breast height age (Table 3). The difference between the two estimates of LC provides an indication of the effect of competition on yields at rotation age. For example, assuming a rotation age of 40 years, the estimated potential yield for these older Norway spruce plantations, had they been free to grow would be 40 years x 10.4 m^3/(ha•a) or 416 m^3/ha. Based on stump age, the comparable yield is 324 m^3/ha (i.e. 40 years x 8.1 m^3/(ha•a) for a difference of 92 m^3/ha (16.4 cords/acre).

Table 3. Comparison of land capabilities based on breast height age and stump age for the older Norway spruce and native softwood species sampled.

Location	Stand #	Species	SA	BHA	HT (m)	LC(BHA) (m^3/ha•a))	LC(SA) (m^3/ha•a))
Dryden Lk.	16	NS	32	24	16.8	13.2	9.8
		rP	33	26	12.8	8.2	6.8
		rS	32	25	9.9	5.8	5.2
		wS	32	25	12.6	8.3	6.9
Blue Mtn.	13	NS	37	32	16.6	9.5	8.4
		rP	33	28	12.4	7.2	6.6
		wS*	56	51	18.2	6.6	6.4
Boars Back	23	NS	46	32	16.7	9.6	6.9
		rP	45	39	18.1	8.6	7.8
Lawrencetown	17	NS	47	37	23.0	13.0	10.4
		wS*	39	30	12.4	6.7	5.5
Caledonia	18	NS	57	47	18.5	7.4	6.4
		bS	57	48	15.2	5.1	4.8
Lorne	22	NS	56	48	26.2	12.2	10.8
		wS*	55	47	19.4	7.9	7.1
Berichan	8	NS	23	13	10.7	13.0+	7.9
		wS	23	15	6.9	6.5	4.9
		rS	23	15	6.4	5.7	4.5
Kirkmount	15	NS	20	13	10.1	13.0	8.5
		rP	20	10	5.9	8.4	4.8
		wS*	47	43	16.0	6.5	6.3
Harmony	19	NS	20	13	9.1	11.3	7.6
		rS	20	13	6.4	7.0	5.3
Average		NS	38	29	16.4	10.4	8.1
		nSwd	37	30	12.3	6.6	5.8

*Natural stand
SA = stump age
BHA = age at breast height (1.35m)
HT = average height of the 5 tallest trees
LC (BHA) = Land Capability based on BHA
LC (SA) = Land Capability based on SA
nSwd = native softwood species
13.0 + = in excess of LC 13

Damaging Agents

Based on observations of the plantations sampled in this study and others, it appears that Norway spruce can recover from white pine weevil attacks with minimal damage to form. Weevil attacks did not usually occur until the tree had reached a height of 5-6 metres and had ceased once the tree had reached a height of 10 metres. The extent of the damage on wood quality for saw timber needs to be examined. Additional studies are required to correlate Norway spruce provenance and weevil susceptibility.

Porcupine damage was noticeable in many of the plantations assessed, although adjacent plantations of red pine often suffered more extensive damage than the Norway spruce. This would suggest that Norway spruce is not the preferred food of the porcupine.

Natural Regeneration

During the last 10 years, older stands of Norway spruce within the province have produced viable seed crops. The most recent cone crop was in 1988 when several operational collections of cones were made. However no naturally regenerated seedlings were observed at any of these plantations. In fact, to the best of our knowledge, no natural Norway spruce regeneration has ever been observed in the province. Further study is required to determine possible strategies for promoting natural regeneration.

SUMMARY

In the fall of 1989, 23 plantations of Norway spruce were sampled and their potential growth compared to that of adjacent native softwood species located on comparable sites. The objective was to better define the increase in yields which can be achieved by planting Norway spruce in Nova Scotia. The major results of this preliminary survey indicate that:

1) Norway spruce has the ability to grow well on a wide variety of sites, potentially outgrowing native softwood species by 1 to 7.8 m^3/(ha•a).
2) The average land capability (LC) based on breast height age, for near rotation age stands of Norway spruce was 10.4 m^3/(ha•a) compared to 6.6 m^3/(ha•a) for native softwood species. This is equivalent to an increase of 58%. Based on a 40 year rotation, Norway spruce could potentially outproduce the average native species by 152 m^3/ha or 27 cords/acre.
3) The highest LC measured was over 13.0 m^3/(ha•a) for a 23 year old stand near the Berichan Road, Colchester County.
4) Most Norway spruce will recover from white pine weevil attack with minimal damage to tree form.
5) Norway spruce is susceptible to porcupine damage but less so than some of our native species.
6) Excess root competition can reduce the LC of near rotation Norway spruce stands by an average of 2.3 m^3/(ha•a). Over a 40 year rotation, this reduction in annual growth is equivalent to a loss of 92 m^3/ha or 16 cords/acre. Grass and/or ericaceous vegetation must be controlled by proper site preparation and weed control in order to realize the full growth potential of this species.

Expanded studies are planned for 1990 and will include stem analyses and actual yields based on permanent sample plot measurements.

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APPENDIX I

DESCRIPTION OF SURVEYED PLANTATIONS AND NATURAL STANDS.

Location	Stand #	Species	SA	BHA	Ht(m)	MAIHT(cm)	Site History	Drainage	Texture	RD(cm)	Elev(m)
Greenfield	1	NS	11	6	4.6	54	Cutover	Mod. well	SCL	50	150
		rP	11	6	4.5	53	"	Mod. well	SCL	40	150
Greenfield	2	NS	11	6	5.0	61	"	Poorly	SCL	30	150
		bS	11	7	4.1	39	"	Mod. well	SCL	45	150
							"				
Glenco	3	NS	8	5	3.7	47		Well	SL	45	60
		bS	8	4	3.2	46	"	Well	SL	40	60
		rP	8	5	3.8	49	"	Well	SL	50	60
							"				
Georgefield	4	NS	12	7	5.5	59		Mod. well	SCL	35	120
		wS	9	5	3.9	51	"	Mod. well	SL	50	120
		rS	9	3	2.5	38	"	Mod. well	SL	30	120
							"				
East Folly Mtn.	5	NS	9	4	3.9	64		Well	L	40	245
		rS	9	4	2.7	34	"	Well	L	40	245
		rP	9	4	2.7	34	"	Well	L	45	245
							"				
East Folly Mtn.	6	NS	9	5	4.5	63		Well	SL	40	150
		rP	9	4	3.4	51	"	Well	SL	45	150
							"				
Upper Debert	7	NS	12	7	6.4	72		Well	SL	35	120
		rP	12	7	5.0	52	"	Well	SL	35	120
							"				
Berichan	8	NS	23	13	10.7	72	Old field	Well	SL	40	305
		rS	23	15	6.9	37	"	Well	SL	35	305
		wS	23	13	6.4	39	"	Well	SL	35	305
Donny Brook	9	NS	9	5	5.0	73	Cutover	Well	SL	50	185
		bS	9	5	3.6	45	"	Well	L	45	185
Lovat	10	NS	17	7	5.7	62	Old field	Well	SiL	50	120
		wS	17	8	5.6	53	"	Well	SiL	50	120
Six Mile Brook	11	NS	17	8	6.2	61	Old field	Well	SL	60	150
		wS	9	4	2.9	39	"	Well	SL	40	90
Kelly Road	12	NS	19	10	6.9	56	Cutover	Well	SL	50	425
		bS	19	10	5.0	37	"	Well	SL	50	425
Blue Mtn.	13	NS	36	32	16.6	48	Old field	"	SL	55	215
		wS*	56	51	18.2	33	"	"	SL	55	215
		rP	33	28	12.4	39	"	"	SL	55	215
Red River Rd.	14	NS	11	7	5.9	65	Cutover	"	SL	40	120
		rP	11	6	4.3	49	"	"	SL	40	120
Kirkmount	15	NS	20	13	10.1	67	Old field	"	SCL	50	150
		wS*	47	43	16.0	34	"	"	SCL	45	150
		rP	20	10	5.9	46	"	"	SL	35	150
Dryden Lake	16	NS	32	24	16.8	64	"	"	SL	55	185
		wS	32	25	12.6	45	"	"	SL	55	185
		rS	32	25	9.9	34	"	"	SL	55	185
		rP	33	26	12.8	44	"	"	SL	55	185
Lawrencetown	17	NS	49	37	23.0	59	Old field	Well	SCL	60	15
		wS*	39	30	12.4	37	"	"	SCL	70	15
Caledonia	18	NS	57	47	18.5	36	"	"	SL	35	90
		bS	57	48	15.2	29	"	"	SL	35	90
Harmony	19	NS	20	13	9.1	60	"	"	SL	35	90
		rS	20	13	6.4	39	"	"	SL	35	90
Otterbrook	20	NS	14	9	6.8	61	Cutover	Imperf.	CL	40	150
		wS	14	9	5.0	41	"	"	CL	40	150
Otterbrook	21	NS	14	9	6.5	57	Cutover	Imperf.	CL	40	150
		wS	14	9	5.2	43	"	"	CL	40	150
Lorne	22	NS	56	48	26.2	52	Old field	Well	SiL	50	125
		wS*	55	47	19.4	38	"	Well	SiL	50	125
Boars Back	23	NS	46	32	16.7	48	Ericaceous	Well	LS	40	60
		rP	45	39	18.1	43	"	Well	LS	40	60

Species: NS - Norway spruce
rP - red pine
wS - white spruce
wS* - white spruce (natural)
rS - red spruce
bS - black spruce

Texture = " soil texture of the B horizon
LS - loamy sand
SL - sandy loam
SCL - sandy clay loam
CL - clay loam
SiL - silt loam
L - loam

SA = stump age
BHA = age at breast height (1.35m)
HT = average height of the 5 tallest trees
MAIHT = mean annual dominant height increment above breast height

RD = rooting depth

Elev = elevation above sea level