The Creation Of A Pedo-Climatic Map And The Development Of The CanSIS-INTERPNB2000 Interpretation Model For Agricultural Crop and Forest Tree Production In New Brunswick

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2002

A collaborative project between:

Agriculture and Agri-food Canada
Fundy Model Forest
Faculty of Forestry and Environmental Management, UNB
New Brunswick Department of Natural Resources & Energy

The project was funded by:

Agriculture and Agri-Food Canada
and the Fundy Model Forest

PRC Contribution No: 02-02

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ACKNOWLEDGEMENTS

The authors wish to thank the members of the soils technical sub-committee of the Fundy Model Forest for encouragement and support of this project. Thanks are also extended to the Potato Research Center of Agriculture and Agri-Food Canada and the management committee of the Fundy Model Forest for making this project possible by funding it.

Thanks are also due to Dr. M.K. Mahendrappa, NRCan, CFS Atlantic, Fredericton, NB for his guidance and to Mr. Darren Allen for the editing of this report.

SUMMARY

A pedo-climatic map for New Brunswick was produced. A Digital Terrain Model (DTM) and Artificial Neural Network (ANN) modeling techniques were employed to create a climate map depicting growing degree-days (GDD) containing 15 GDD classes at a 220-meter resolution.

The existing forest soils of New Brunswick map was intersected using a Geographic Information System (GIS) with the GDD map to produce a pedo-climate map that contains over one million polygons of 21280 unique listings. The pedo-climatic map polygon attribute file was used to create the database for the study in the form of PAT, SMUF, SNF and SLF files.

The CanSIS97 interpretation model for agricultural crop and tree production was updated by incorporating aspect and GDD criteria to form a new model: CanSIS_INTERPNB2000

This model was then applied using the database produced by the pedo-climate map of New Brunswick generating interpretations for the production of six agricultural crops and twelve forest tree species. It is thought that the above study may enhance the predictability of the CanSIS_INTERPNB2000 interpretation model to higher levels than that of the predictability obtained by the older CanSIS97 version model of interpretation for the above species.

INTRODUCTION

Since the publication of the report titled: *Forest Soils Interpretation for Tree Production in the Fundy Model Forest in 1997*, the CanSIS 97 interpretation model has undergone considerable improvements. These improvements incorporated slope and aspect into the model and testing of the model for several areas in New Brunswick by a third party (forest industry).

From these tests, an average of 14% overestimation, 36% underestimation and 50% right-on estimation of the model prediction were obtained when compared with productivity values obtained from the field.

These predictabilities for the test areas were accepted by foresters but considered conservative with the need for enhancements.

It is well known that climate plays an important role in tree growth and its incorporation into the soil model may result in an enhancement of the overall predictability of the model. The level of enhancement will result in a reduction of the "50% uncertainty" category of the model's estimation.

In this study and based on relations of land–surface attributes and aboveground daytime temperature, a newly developed technique (Bourque et al., 1998), expressed in Growing Degree Days (GDD) and interpreted by way of a fully trained Artificial Neural Network (ANN), a Growing Degree Day climate map was generated. This along with the application of a Digital Terrain Model (DTM) of New Brunswick a grid cell resolution of 220 meters is obtained.

The software program of the CanSIS97 soil interpretation model was re-written and modified to accommodate the GDD climate factor. The model is renamed CanSIS-INTERPNB2000.

The generated GDD climate map was linked with the existing forest soil map of New Brunswick using GIS techniques to produce the new Pedo-Climatic map. A new Polygon Attribute file (PAT) for this map was generated.

This PAT file was then used by the CanSIS-INTERPNB2000 model to generate the following files : Soil Map Unit File (SMUF), Soil Name File (SNF), the Soil Layer File (SLF) and finally the Pedo-Climate Map Unit Interpretation file (PCMUI) for agricultural crop and tree production for New Brunswick.

METHODS

GROWING DEGREE DAY (GDD) CLIMATE MAP FOR NEW BRUNSWICK

Plant metabolic processes and growth increases with temperature (Nilsen and Orcutt 1996), as a result plant growth correlates fairly well to measures of annual heat inputs. A common measure of heat input and thus plant growth is growing degree-days (GDD). Degree-days are determined by summing the daily difference between the daily mean temperature and a minimum threshold temperature (Kimmins 1997) below which plant metabolic and growth processes cease (Nilsen and Orcutt 1996).

Regional distribution of GDD is exceedingly variable and in most instances difficult to capture with the current level of weather monitoring. This problem is particularly pronounced in remote areas where the level of monitoring is minimal to non-existent.

The degree of variability, save the effects of changing air masses, sky cloudiness and atmospheric transparency, is controlled to a large measure by the underlying topography (i.e., local increases in topographic relief, slope angles, slope orientation, proximity to water bodies), geographic position, and vegetation cover that make up the regional landscape (Running et al. 1987; Rosso 1994; Dubayah and Rich 1996; Thornton et al. 1997).

The artificial neural network modeling technique calculating a GDD surface for the province of New Brunswick is presented.

Calculations of GDD are performed for the spring-to-autumn growing period, from April 1 (approximate date of bud burst) to October 20 (approximate end date of leaf fall), and represent the long-term average growing conditions across the province.

Artificial Neural Networks

Artificial neural networks (ANN) are flexible computational networks that can be used to describe complex nonlinear relationships between related variables (Cook and Wolfe 1991; Park et al. 1994; Hsu et al. 1995; Anderson 1995; Ripley 1996).

ANN’s develop models through learning rather than programming. Unlike regression methods, ANN’s provide a unique way of modelling patterns in data without requiring assumptions to be made about the underlying form of the patterns between the input and output variables of a dataset. This property is particularly useful when trying to quantify nonlinear relationships in complex datasets.

Training of the neural network is based on the generalized Delta rule or backward error propagation method (Ripley 1996).

The network generates output values according to the values contained in a training input matrix and internal weights. Based on discrepancies between the projected and target (training) output, the network updates its internal weights (connections) by means of a gradient descent algorithm (Ripley 1996).

With successive adjustments of the internal weights, the discrepancy between the ANN-generated output values and target values is reduced.

Once the network is suitably trained (the projected and target output values are sufficiently close to one another) the network generates exceedingly quick predictions for every new set of input conditions supplied to it.

Degree-Day Map Development

A total of 30 temperature data loggers were installed in forest canopies for different slope angles at different landscape directions and elevations to collect daily temperatures at set intervals during the growing season (April to October). The growing degree days was extrapolated for the 30 year normal period (1971-2000).

Fifteen growing degree-day GDD classes were assigned and four suitability classes were determined for each tree species of the study.

Map development was based on a spatial treatment of GDD's applied across a gridded domain representing the province of New Brunswick (Fig. 1). Digital Terrain Model (DTM) grid-point coordinates (x, y; in meters) are expressed in New Brunswick Double Stereographic projection (Datum: ATS77).

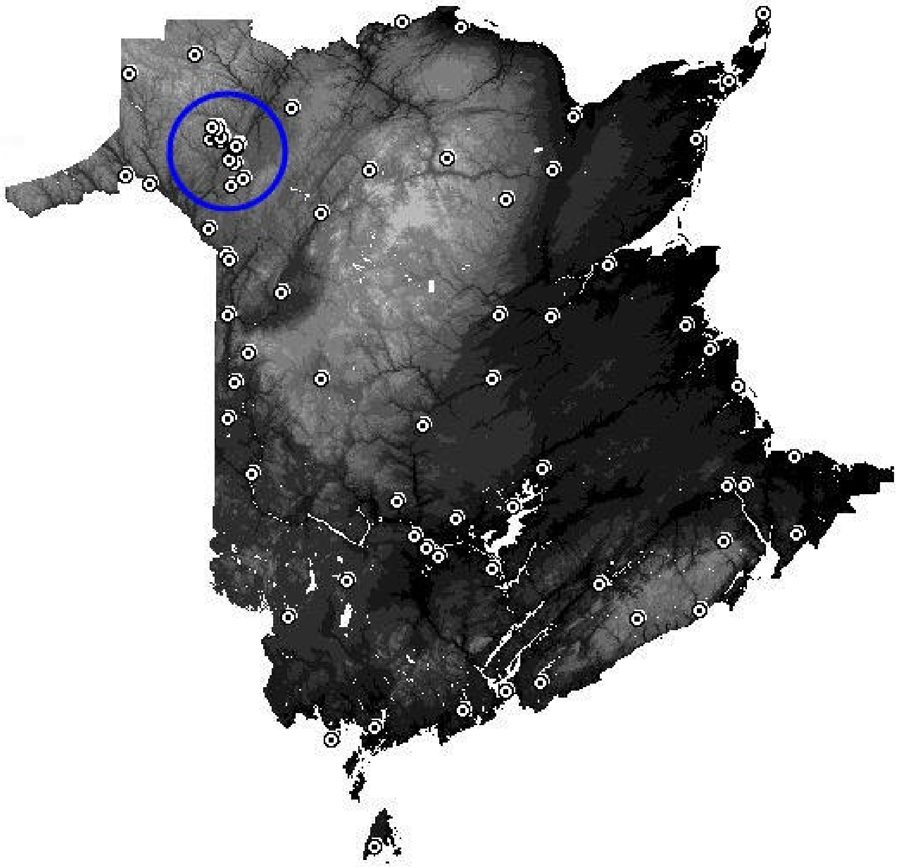

Fig. 1. Digital Elevation Model (DEM) for the province of New Brunswick. The darker gray to black colours represent the lower elevation areas of the province (~ 0-50 m) and the lighter gray colours, the higher elevation areas (~750 m). The open symbols indicate the locations of Environment Canada weather stations and remote temperature data loggers(circled) used in this study.

Land-Surface Characterization

Growing degree-day fields are calculated according to x, y, elevation (z), and point-calculations of slope (Ψ), aspect (Θ), and slope position (Σ). The slope position specifies the elevation difference between the grid point of interest and the stream segment closest to it (pers. comm., Meng, 2001). Because spatial quantities x, y, z, Ψ , Θ , and Σ vary from node to node, they are indexed according to their position in the grid. Grid position is normally given according to column-row position, with “i” indicating the column number (along the x-axis; from west to east) and “j” the row number (along the y-axis; from south to north).

Node values of slope (Ψ) and aspect (Θ) are determined locally [i.e. for each grid-point i,j] from the centered-finite difference form of the directional derivatives (i.e. $\partial z/\partial x$ and $\partial z/\partial y$, where x and y are the grid-point coordinates and z is the corresponding elevation):

$$\Psi_{i,j} = \tan^{-1}\left\{\left[\left(\frac{z_{i+1,j} - z_{i-1,j}}{2\Delta s}\right)^2 + \left(\frac{z_{i,j+1} - z_{i,j-1}}{2\Delta s}\right)^2\right]^{1/2}\right\} \qquad (1)$$

and

$$\Theta_{i,j} = 90\left(\frac{z_{i+1,j} - z_{i-1,j}}{\left|z_{i+1,j} - z_{i-1,j}\right|}\right) - \tan^{-1}\left(\frac{z_{i,j+1} - z_{i,j-1}}{2\Delta s} \bigg/ \frac{z_{i+1,j} - z_{i-1,j}}{2\Delta s}\right) \qquad (2)$$

where Δs represents the actual distance on the ground (resolution) between individual grid-points of the DEM. Slope aspect (Θ , in degrees) is calculated as negative east of south and positive west of south. In this study, grid-point separations in both the x- and y-directions are taken to be 220 m. Subscripted notation "i+1,j" and "i-1,j" refer to grid points to the east and west of reference grid point i,j, and subscripts "i,j+1" and "i,j-1" to the grid points to the north and south of grid point i,j.

Mathematically, the slope position is given by

$$\Sigma_{i,j} = (z_{i,j} - z_{stream}) \quad (3)$$

where z_{stream} is the elevation (in metres) of the stream segment closest to it (Meng, 2001; manuscript in preparation).

Interpolation of Growing Degree-Days

Training of the ANN (see Fig. 2 for structure illustration) is based on:

Geographic position (x, y; columns 2-3, Table 1) and land-surface characteristics (i.e., elevation, slope angle, aspect, and slope position; columns 4-7, Table 1) determined at each of the temperature monitoring sites (Fig. 1) by direct measurement and/or DTM calculation; and Point-calculations of GDD, i.e.,

$$= \sum_{GS}\left(\overline{T} - T_{base}\right) > 0.0, \qquad (4)$$

Where $\overline{T}$ is the mean daily temperature, T_{base} is the threshold temperature, and GS represents the growing season, are based on temperatures measured at 54 Environment Canada weather stations and with 33 remote temperature sensing data loggers (HOBO trademark) placed in various slope-aspect-elevation combinations in northern NB (column 8, Table 1), and a base temperature of 5.6^{o}C (after Urban 1990).

Slope position is considered in the ANN in order to account for the effects of the drainage of cold air at night on the accumulation of GDD's along valley slopes (Geiger 1965; Kimmins 1997).

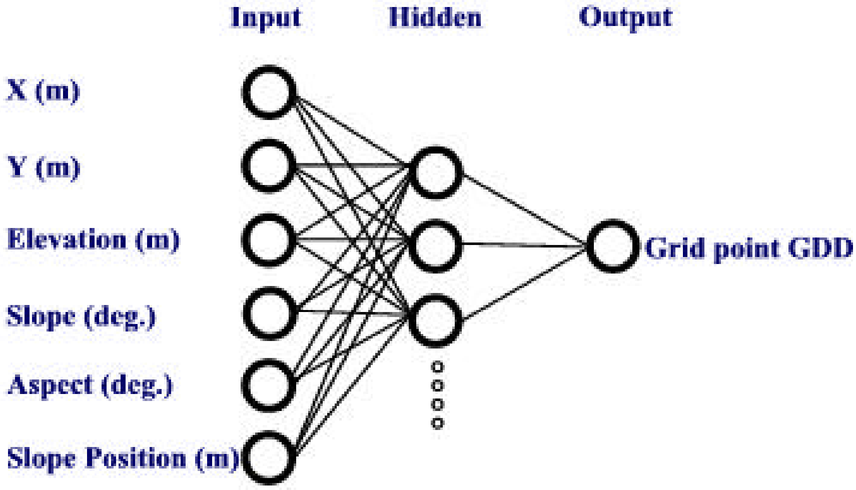

Fig. 2. Representation of the artificial neural network constructed to calculate node GDD's. Calculated output is compared to actual values and connecting weights (represented by the lines) are adjusted iteratively so that convergence between predicted and observed values is achieved. The units on the left hand side of the diagram serve as input units to the ANN, while the unit on the right hand side serves as the output unit. The middle units (the hidden units) serve as processing units within the ANN structure.

Table 1. Site characteristics and GDD for the Environment Canada weather stations (station ID's > 8100000) and the miniaturized temperature sensors (station ID's < 200) used in this study.

Station ID	X	Y	Z	Slope	Aspect	Slope position	Mean GDD[a]
151	210743	909703	283.2	5.4	111.4	14.6	1125.0
152	214817	896044	265.9	5.1	-127.8	22.9	1181.4
154	210939	903175	316.5	0.9	-44.2	3.1	929.2
155	208557	904989	321.5	3.6	110.4	23.2	1138.6
156	199810	913883	276.2	6.5	79.1	2.4	977.8
157	210647	909990	257.9	3.9	146.2	15.2	1152.0
158	212321	911487	271.8	9.9	104.9	32.0	1327.9
159	208390	904928	301	8.6	87.9	29.4	1196.6
160	200745	919589	363.8	6.7	-38.1	14.5	1105.3
161	211186	909685	310.1	0.4	-22.4	8.7	1158.7
162	204621	913829	295.4	4.6	58.2	2.4	992.8
163	210804	909517	295.6	5.2	94.8	8.1	1158.8
164	202753	919220	360.5	3.4	-85.4	3.9	1070.9
165	204307	914738	337.1	5.9	26.2	18.0	1152.4
166	203048	918989	328.2	6.6	-71.6	11.2	1082.0
169	205358	914656	308	4.7	-77.3	0	1082.5
170	209355	892683	207	0.9	-88.8	0	1149.2
171	214958	896306	243.6	3.3	-91.3	11.3	1282.3
172	203967	914400	300.1	7.8	71.3	3.1	1051.8
173	204144	913273	274.5	2.5	56.0	2.1	1004.3
174	208236	904882	279.3	7.6	91.9	23.3	1183.3
175	210998	910311	258.2	2.9	-167.9	3.6	1170.3
176	208809	892914	229.5	5.5	-81.1	11.4	1175.9
177	211535	911193	219	6.6	146.8	8.2	1256.7
178	201102	919429	340.9	2.8	-66.9	8.3	1046.6
179	214893	896181	251.4	4.1	-121.1	19.4	1128.8
180	204127	914534	321.5	5.2	22.6	12.9	1102.3
181	203183	918865	308.9	7.1	-78.6	11.8	1090.4
182	200476	919710	391.9	8.1	29.9	16.4	1142.2
183	249527	880800	170	0.1	-117.9	0.9	1319.0
184	198884	873111	244	2.6	-2.4	2.5	1381.0
186	231428	844854	160	3.1	-7.4	7.4	1441.0
188	172780	893999	144.9	7.6	33.7	0	1287.0
8100100	310848	742213	61	1.0	-63.6	1.9	1491.6
8100200	420923	701147	43	4.4	-128.9	12.1	1318.7
8100300	207639	834056	91	5.6	71.3	11.7	1545.7
8100430	431183	732486	183	5.8	89.0	28.3	1390.0
8100500	363908	923741	12	0.9	-161.5	6.2	1394.8
8100512	211014	803988	91	4.7	-142.9	26.9	1554.0
8100566	217333	817239	442	1.6	-121.1	11.2	1273.0
8100590	437361	802668	11	0.6	-92.1	2.0	1544.0
8100701	286566	966774	26	0.4	-25.4	3.1	1457.4
8100850	207692	787362	143	1.6	55.9	4.6	1439.0
8100880	312692	964548	38	0.6	-62.1	5.4	1281.0
8101000	379077	857213	34	0.1	-37.4	1.2	1583.0
8101100	349411	764632	11	1.1	108.8	2.2	1558.7
Station ID	X	Y	Z	Slope	Aspect	Slope position	Mean GDD[a]
8101301	161767	897212	152	3.1	-29.1	11.4	1531.9
8101500	297670	728867	17	0.3	21.0	3.0	1647.6
8101600	291466	734429	40	0.6	-46.9	1.7	1638.8

8101800	327218	720035	53	2.0	-81.9	9.1	1735.7
8101900	206547	861868	152	3.1	20.2	11.1	1511.1
8101904	208792	859609	229	3.9	-124.3	22.5	1490.6
8102200	261082	714540	152	1.4	-40.5	11.4	1587.8
8102275	249388	805769	259	0.2	177.9	1.2	1302.0
8102300	236141	928188	274	2.2	-9.8	3.1	1231.9
8102325	414580	829990	35	0.2	-38.7	0.5	1528.0
8102350	333288	886799	341	0.3	-74.2	5.0	1323.0
8102600	235223	698085	140	1.5	-156.1	2.1	1577.8
8102800	295383	784441	177	1.4	-162.7	5.2	1385.0
8102808	329764	834532	53	0.8	-35.1	4.0	1607.1
8103000	336385	747869	23	0.4	-70.2	0	1626.4
8103100	432981	756984	12	0.2	-61.4	0	1619.0
8103200	440712	757157	71	1.2	-17.2	2.9	1558.7
8103400	313358	655528	15	1.0	-36.7	11.7	1322.2
8103500	354348	900296	106	3.9	-156.1	3.7	1439.9
8103800	303108	725533	46	0.7	68.9	6.7	1626.4
8104300	353433	833584	46	0.9	-122.8	2.6	1410.0
8104400	425505	819089	5	0.5	146.9	6.1	1570.5
8104480	283749	750005	116	2.6	-145.8	2.2	1470.9
8104500	464497	735509	24	0.9	-64.9	7.9	1504.9
8104600	254330	642343	15	2.3	-36.1	1.5	1493.8
8104700	274038	647787	34	0.6	179.1	14.8	1493.3
8104800	332955	664492	31	2.1	64.1	9.2	1434.1
8104900	348621	667928	109	5.0	115.9	0	1374.2
8105042	192995	952170	274	4.5	82.1	24.7	1306.0
8105100	162858	943901	412	10.7	-28.4	12.4	1106.0
8105200	375527	712656	21	9.3	116.2	3.3	1706.3
8105551	306787	905609	625	3.5	67.6	28.8	1070.0
8105600	218906	762747	55	3.7	10.4	15.4	1659.8
9999991	271923	899673	784.4	7.5	114.1	51.2291	856.0
9999992	392483	697053	215	3.9	-48.3	11.0814	950.9
8103050	449206	970524	1	0.3	-103.3	0.983567	1314.4
8104458	463298	770690	6.6	0.4	-141.5	2.588416	1488.3
8109937	273553	594440	11.3	2.5	35.4	24.003441	968.3
8104975	433721	940485	5.3	0.1	40.9	0	1481.2
8105505	419250	914222	13	1.0	-105.1	3.250797	1325.4

[a]Point-calculations of GDD are based on one-year April to October hourly temperatures, in the case of the remote temperature data loggers(HOBO), and 30-years of maximum and minimum temperatures, in the case of the Environment Canada weather stations.

Adjustments to the GDD’s calculated from the temperatures recorded with the HOBO temperature loggers are made to better reflect long-term mean growing conditions during the normal period (i.e., 30-year period spanning from 1961 to 1990). No such adjustment is applied to the Environment Canada mean GDD values calculated. This long-term representation of GDD is a reasonable indicator of tree growth because forest trees are long-lived and as a result, tend to integrate many years, often up to 70 to 150 years or more, of growing conditions. Adjustments to the GDD are based on the GDD’s calculated at several Environment Canada weather stations in proximity to the HOBO sensor array (Fig. 1).

To ensure ANN-calculations of GDD are bounded, several points were added in remote areas where meteorological data was not readily available. One such point is in the high elevation areas of central NB, and another in the Fundy Highlands. These two points appear as 9999991 and 9999992 in Table 1. Their GDD values are estimated by assuming a constant atmospheric lapse rate of 6.5^{o}C/km.

Following training, network calculations are applied across the DEM-grid on a grid point by grid point basis, each evaluation based on the input of point-estimates of geographic position and land-surface characteristics available at each of the grid points of the DEM.

Because of the small dataset used for training the ANN (87 records), reasonable levels of convergence between the projected and target output values are achieved fairly quickly (> 15 minutes) with a 1.4-GHz Pentium machine.

Land-Surface Conditions (Input to ANN)

Figure 3 shows slope, aspect, and slope position as determined from the DEM (Fig. 1). The darker grays and blacks correspond to low values. The whites/light grays correspond to high values.

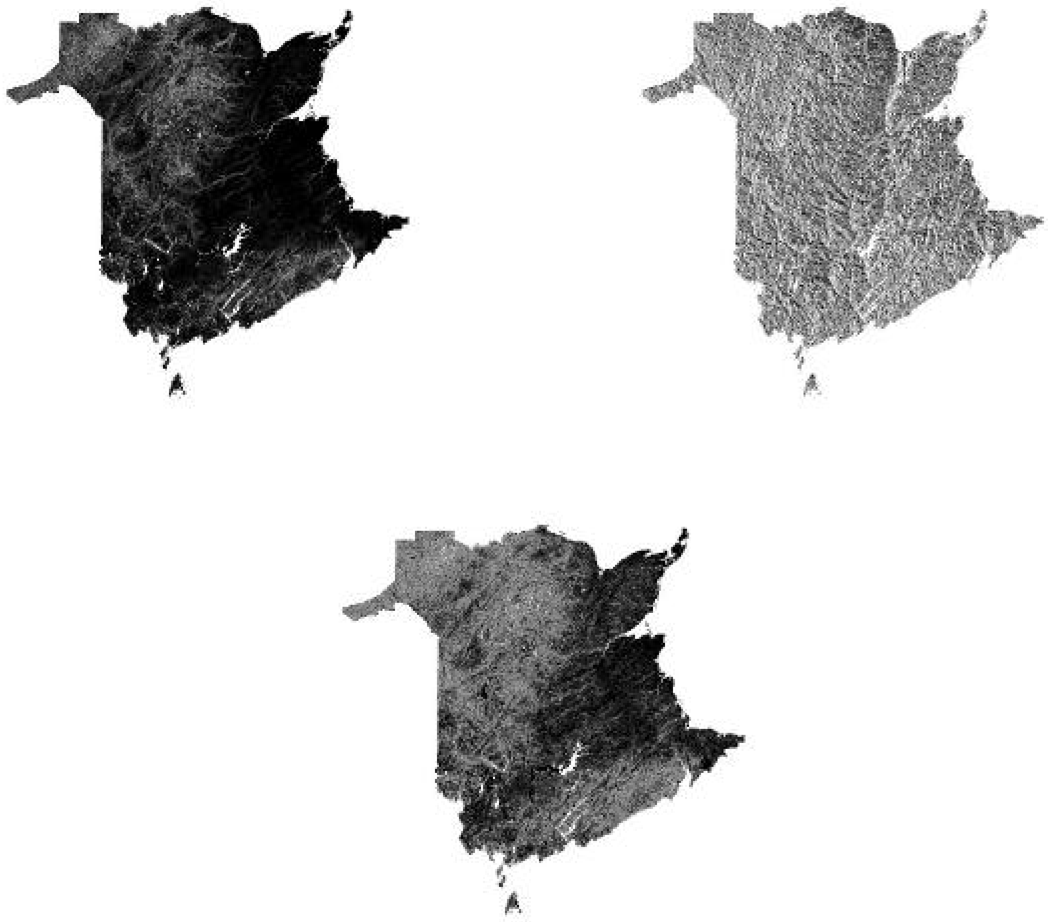

Fig. 3. Distribution of slope (upper left), aspect (upper right), and slope position (lower map) across the province of NB.

PEDO-CLIMATE MAP, SOIL DATABASE, AND THE CANSIS-INTERPNB2000 MODEL DEVELOPMENT

With the increased application of computer technologies to data handling, electronic polygon and map attribute data files also became available for soil surveys. This data is stored nationally in the National Soils DataBase (NSDB) in the Canada Soil Information System (CanSIS), and provincially in the New Brunswick Agricultural Land Information System (NB'ALIS'). Both CanSIS and NB'ALIS' are based on commercially available Geographic Information Systems (GIS).

GIS is designed to manage and manipulate large volumes of information that are spatially oriented. The ability to handle relationships among locations is the geographic feature of a GIS that sets it apart from a standard data base information system. It also has analytical capabilities. CanSIS uses ARC/INFO software while NB'ALIS' uses CARIS (Computer Aided Resource Information System) software. Data exchange protocols have been established between the two systems to ensure that information can be easily transferred back and forth. These systems are also compatible with most other land information systems.

CanSIS 97, which is a model in development, is used to interpret soil map units for tree and agricultural crop production. This model was used in 1997 to interpret soils for the production of 12 tree species in the Fundy Model Forest, the model is based on the interaction between soil data base and a number of look up tables of soil properties and site characteristics suitable for tree and agricultural crops production. Three aspect classes were generated using the Province of New Brunswick's Digital Terrain Model resulting in a new forest soil map which included the aspect of each polygon. The aspect criteria were incorporated into the CanSIS79 model and the model was then tested by the private sector of the forest industry in New Brunswick. Test results were mentioned previously in the second paragraph of the introduction section of this report.

These results were considered conservative by industry and hence the idea of using a climate factor such as growing degree days GDDs was suggested for incorporation in the CanSIS97 model. Fifteen classes of GDDs were established in this study and incorporated in the interpretation model. A suitability look up table of GDDs was also included in the model.

The generated GDD climate map was then merged/intersected with the existing forest soil map of New Brunswick (Colpits et al., 1995) to produce a pedo-climatic map of the province. A polygon attribute file (PAT), a soil map unit file (SMUF), a soil name file (SNF) and a soil layer file (SLF) were generated as database. The SMUF file format was modified to accommodate the aspect and GDD criteria. The CanSIS97 model software was re-written to accommodate the GDD and aspect.

At this point, the name of the upgraded and updated CanSIS97 model is changed to: CanSIS-INTERPNB2000.

The Algorithm

The CanSIS-INTERPNB2000 is a model built on a Microsoft Access 2000 platform using Visual Basic VB 6.0 programming. The CanSIS-INTERPNB2000 is comprised of two sections:

1-The database
2-The interpretation of unique soil (pedo-climate) map unit polygons for tree and agricultural crop production.

The pedo-climate map unit interpretation (section two) includes the software that is dependent on a- the information in the database found in section one and b- suitability look-up tables for different species.

The CanSIS-INTERPNB2000 model performs the following:

1- It identifies the polygon symbol (map unit) from the unique listing, the soil code, and a modifier all found in the SMUF file, then, this is linked to the SLF file and sets all ratings for that specific map unit to 0 (not rated) then goes through a sequence of loops to determine the suitability class of that specific polygon for the species required. Starting with texture, depth, etc….
2- Finds and assigns a ***Texture*** class from the percent sand, silt and clay for friable solum layers of bulk density < 1.65 g/cm^3 from the SLF taking coarse fragments content into account.
3- Adjusts the rating and assigns a suitability class to the map unit through the look up process using the texture class / suitability rating look up table for each of the specie
4- Finds and assigns a ***Depth*** class of friable soil (bulk density< 1.65g/cm^3).
5- Adjust the rating and assigns a suitability class to the map unit using the depth class / suitability rating look up table for each specie
6- If the rating class is greater than the rating in step # 2 & 3 above (signifying a lower suitability, ie, 1 = Good, 2 = Fair, 3 = Poor, and 4 = Unsuitable) then the rating class is changed. If the rating class is less than the rating in step # 2 & 3 it ignores it.
7- Finds and assigns Rockiness from SMUF, adjusts rating as in step # 5 & 6

And so on for ***Slope***, ***Drainage***, etc … from SMUF. Finally it looks up fertility class for this specific soil code, adjusts ratings for this class and adds ratings to the pedo-climate map unit interpretation (PSMUI) file with an extension symbol that justifies or explains the rating. G = Good, F = Fair, P = Poor, U = Unsuitable, and f = fertility, w = wetness, etc…

Electronic Data Files

Polygon data is essentially line information to define the map polygon boundaries and location. It is stored in a series of x-y coordinates referenced to a base map. This defines the geographic location aspect of the map polygon. Each polygon has an associated reference to link it with specific map attribute files that describe the polygon.

As a system serving agricultural, forestry, and environmental needs, the information stored in these attribute files is primarily concerned with the biological productivity of the soils. Biological productivity is controlled mainly by the availability of energy, water, and nutrients.

In agricultural settings, the supply of plant nutrient is manipulated by management. In forestry setting this supply is dependent primarily on the fertility of the parent material of the soil Therefore, the ability of soils to supply water to growing plants is the focal point of these files. This does not preclude their use for other applications, but rather indicates that they may at times be lacking in some specific properties required to make an assessment.

Core properties of these attribute files consist of the following features:

- Drainage
- Water table
- Rooting depth
- Texture
- Organic matter
- PH
- Base saturation
- Cation exchange capacity
- Water holding capacity
- Saturated hydraulic conductivity
- Bulk density
- Electrical conductivity
- Slope
- Stoniness
- Taxonomy to the Subgroup level
- State of decomposition (Organic soils)
- Wood content (Organic soils)

In this study, the site criteria (1) aspect and (2) climate as a growing degree day (GDD) class were included in the attribute files.

File Structure

The data is stored in five related files:

Polygon Attribute Table File (PAT) - links map polygons to soil map units.

Soil Map Unit File (SMUF) - links soil map units to soil names and landscape modifiers.

Soil Names File (SNF) - links soil names to attributes that pertain to the whole soil.

Soil Layer File (SLF) - links soil names to attributes that vary in the vertical direction.

***The Polygon Attribute Table File (PAT)*:** The purpose of the polygon attribute table file is to link polygon numbers to soil map units. For the purpose of this discussion, a soil map unit is the entire symbol found within a polygon drawn on the soil map.

The list of attributes for the PAT file is as follows:

Field	Field name	Type	Width	Dec
1	Area	Floating	4	3
2	Perimeter	Floating	4	3
3	Soil #	Binary	4	
4	Soil-ID	Binary	4	
5	Mapunitnom	Char	60	

PAT File name descriptions are listed below:

AREA	Area of polygon in square meters
PERIMETER	Perimeter of polygon in meters
SOIL#	Internal system number
SOIL - ID	Polygon number
MAPUNITNOM	Map symbol

***The Soil Map Unit File (SMUF)*:** The list of attributes for the SMUF file is as follows:

Field	Field name	Type	Width	Dec
1	PROVINCE	CHAR	2	
2	MAPUNITN	CHAR	60	
3	ASPECT	NUMERI	2	
4	CLIMATE	CHAR	1	
5	SOIL-	CHAR	3	
6	CODE1	CHAR	3	
7	MODIFIER1	NUMERI	3	
8	EXTENT1	CHAR	3	
9	SOIL-	CHAR	3	
10	CODE2	NUMERI	2	
11	MODIFIER2	CHAR	3	
12	EXTENT2	CHAR	3	
13	SOIL-	NUMERI	2	
14	CODE3	NUMERI	5	
15	MODIFIER3	NUMERI	5	
16	EXTENT3	NUMERI	5	
17	SLOPEP1	CHAR	1	
18	SLOPEP2	CHAR	1	
19	SLOPEP3	CHAR	1	
20	STONE1	CHAR	8	
	STONE2			
	STONE3			
	DATE			

SMUF file name descriptions are listed below:

PROVINCE	Code for province, i.e., NB for New Brunswick
MAPUNITNOM	Soil map unit symbol as coded in CanSIS from the original paper map
ASPECT	Two character code
CLIMATE	One character code
SOIL_CODE	Three character code for the soil name (SOIL_CODE1, SOIL_CODE2, SOIL_CODE3)
MODIFIER	Three character code to show soil variations. The modifier applies to the soil name and the soil code (MODIFIER1, MODIFIER2, MODIFIER3)
EXTENT	Percent of the map unit occupied by specific soil
SLOPE	Slope steepness in percent(SLOPEP1, SLOPEP2, SLOPEP3)
STONE	Stoniness class(STONE1, STONE2, STONE3)
DATE	Date of last revision

***The Soil Names File (SNF)*:** This file contains information that applies to the entire soil. The list of attributes for the SNF file is as follows:

Field	Field name	Type	Width	Dec
1	PROVINCE	CHAR	2	
2	SOILNAME	CHAR	24	
3	SOIL-CODE	CHAR	3	
4	MODIFIER	CHAR	3	
5	LU	CHAR	1	
6	KIND	CHAR	1	
7	WATERTBL	CHAR	2	
8	ROOTREST	CHAR	1	
9	RESTR-TPE	CHAR	2	
10	DRAINAGE	CHAR	2	
11	MDEP1	CHAR	4	
12	MDEP2	CHAR	4	
13	MDEP3	CHAR	4	
14	ORDER	CHAR	2	
15	S-GROUP	CHAR	4	
16	G-GROUP	CHAR	3	
17	PROFILE	CHAR	14	
18	DATE	CNAR	8	
19	SLFNA	CHAR	1	

SNF file field name descriptions are listed below:

PROVINCE	See Soil Map Unit File
SOILNAME	Assigned soil name i.e., Caribou
SOIL_CODE	See Soil Map Unit File
MODIFIER	See Soil Map Unit File
LU	Land use (agriculture or native)
KIND	Kind of soil (mineral, organic, etc.)
WATERTBL	Water table characteristics
ROOTRESTRI	Soil layer that restricts root growth
RESTR_TYPE	Type of root restricting layer
DRAINAGE	Soil drainage class
MDEP	Mode of deposition (MDEP1, MDEP2, MDEP3)
ORDER	Soil order (Canadian System of Soil Classification, CSSC)
S_GROUP	Soil Subgroup (CSSC)
G_GROUP	Soil Great Group (CSSC)
PROFILE	Representative soil profile reference
DATE	Date of last revision
SLFNA	Denotes presence of soil layer file records

***The Soil Layer File (SLF)*:** This file is designed to handle attributes which vary in a vertical direction, i.e., soil profile information. The mean value is reported for each attribute. The method of analysis is listed in the project file.

The list of attributes for the SLF file is as follows:

Field[1]	Field name	Type	Width	Dec
1	PROVINCE	CHAR	2	
2	SOIL-CODE	CHAR	3	
3	MODIFIER	CHAR	3	
4	LU	CHAR	1	
5	LAYER NO	CHAR	1	
6	HZN-LIT	CHAR	1	
7	HZN-MAS	CHAR	3	
8	HZN-SUF	CHAR	5	
9	HZN-MOD	CHAR	1	
10	UDEPTH	NUMERIC	3	
11	LDEPTH	NUMERIC	3	
12	COFRAG	NUMERIC	3	
13	DOMSAND	CHAR	2	
14	VFSAND	NUMERIC	3	
15	TSAND	NUMERIC	3	
16	TSILT	NUMERIC	3	
17	TCLAY	NUMERIC	3	
18	ORGCARB	NUMERIC	5	
19	PHCA	NUMERIC	4	
20	PH2	NUMERIC	4	
21	BASES	NUMERIC	2	
22	CEC	NUMERIC	3	
23	KSAT	NUMERIC	5	
24	KPO	NUMERIC	3	
25	KP10	NUMERIC	10	
26	KP33	NUMERIC	3	
27	KP1500	NUMERIC	3	
28	BD	NUMERIC	5	
29	EC	NUMERIC	3	
30	CAC03	NUMERIC	2	
31	VONPOST	NUMERIC		
32	WOOD	NUMERIC		
33	DATE	DATE		YY.MM.DD

[1]Note: For fields 12 and 14-32, a three digit numeric field for the number of observations is optional. A code of zero (0) indicates an estimate.

SLF file field name descriptions are listed below:

PROVINCE	See Soil Map Unit File
SOIL_CODE	See Soil Map Unit File
MODIFIER	See Soil Map Unit File
LUSee	Soil Names File
LAYER_NO	1-9, Horizon number
HZN_LIT	Canadian System of Soil Classification (CSSC) horizon lithological discontinuity
HZN_MAS	CSSC master horizon (upper case)
HZN_SUF	CSSC horizon suffix (lower case)
HZN_MOD	SSChorizon modifier
UDEPTH	Upper horizon depth (cm)
LDEPTH	Lower horizon depth (cm)
COFRAG	Coarse fragments (% by volume)
DOMSAND	Dominant sand fraction size
VFSAND	Very fine sand (% by weight)
TSAND	Total sand (% by weight)
TSILT	Total silt (% by weight)
TCLAY	Total clay (% by weight)
ORGCARB	Organic carbon (% by weight)
PHCA	pH in calcium chloride
PH2	pH in water
BASES	Base saturation (%)
CEC	Cation exchange capacity (meq/100g)
KSAT	Saturated hydraulic conductivity (cm/h)
KP0	Water retention at 0 kilopascals
KP10	Water retention at 10 kilopascals
KP33	Water retention at 33 kilopascals
KP1500	Water retention at 1500 kilopascals
BDBD	Bulk density of the soil matrix (g/cm^3)
EC	Electrical conductivity (dS/m)
CAC03	Calcium carbonate equivalent (%)
VONPOST	von Post estimate of decomposition
WOOD	Volume (%) of woody material
DATE	Date of last revision

While application of the data sets using a GIS allows for the ability to display results geographically, the lack of such a system does not preclude analyses of the attribute file information. These data files are easily uploaded to a personal computer and can be analysed with any number of commercial database management software programs. The interpretations presented in the next section of this report are based on these files.

RESULTS AND DISCUSSION

GROWING DEGREE-DAYS (ANN Output)

ANN Training. Results from training the ANN for GDD is provided in Figure 4. This figure compares the ANN-projected (horizontal axis) and observed (vertical axis) values. For perfect agreement, the data points should align perfectly along the 1:1 correspondence line (red diagonal line). Statistically, the value of the slope of the regression line fitted to the data is no different from unity at the 95% confidence level. This indicates that the trained ANN for the most part should be able to produce results sufficiently close (within 25 GDD) to observed values. The trained ANN is able to explain about 98.6% of the variability revealed in the training dataset (Table 1).

Analysis of internal ANN connection weights revealed that the calculation of GDD was most affected by geographic position, in particular the y-coordinate (latitude). Its contribution to the calculation of the output accounted for 44.8%. Elevation contributed 13.0% to the calculation of the output and the x-coordinate, contributed 12.8%. Together, the remaining variables (Fig. 2) contributed 29.4% towards the calculation of the output.

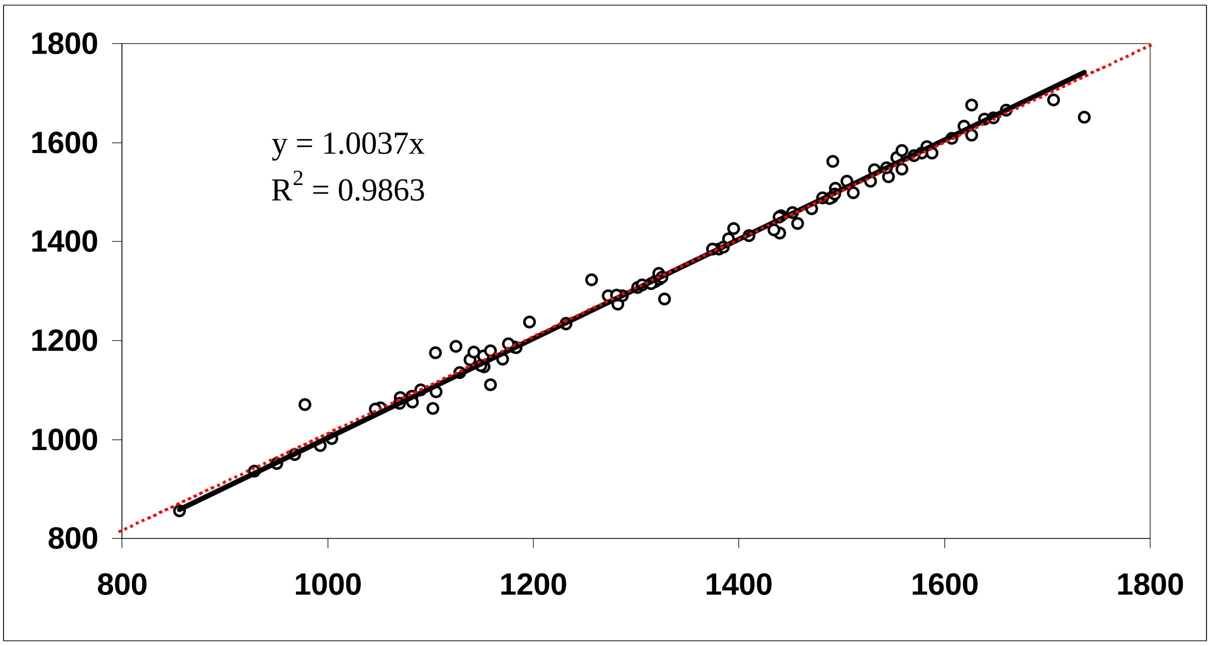

Fig. 4. Scatter diagram of ANN-predicted (horizontal axis) versus observed mean GDD (vertical axis).

Application of ANN. Figure 5 shows the spatial distribution of GDD's as predicted with the trained ANN. A side-by-side comparison of the new GDD map with a contour map of the same variable for the Maritime Provinces (Fig. 6) indicates similar patterns at the provincial scale. The new GDD map, however, provides greater detail at the local scale, within the 220-m resolution limit.

GROWING DEGREE DAY CLIMATE AND PEDO-CLIMATIC MAPS

Fig. 5. Surface map of GDD's for the province of NB. The darker gray and black colours coincide with low mean GDD's (~800 – 900) and the light gray and white colours, high mean GDD's (~1700 – 1800).

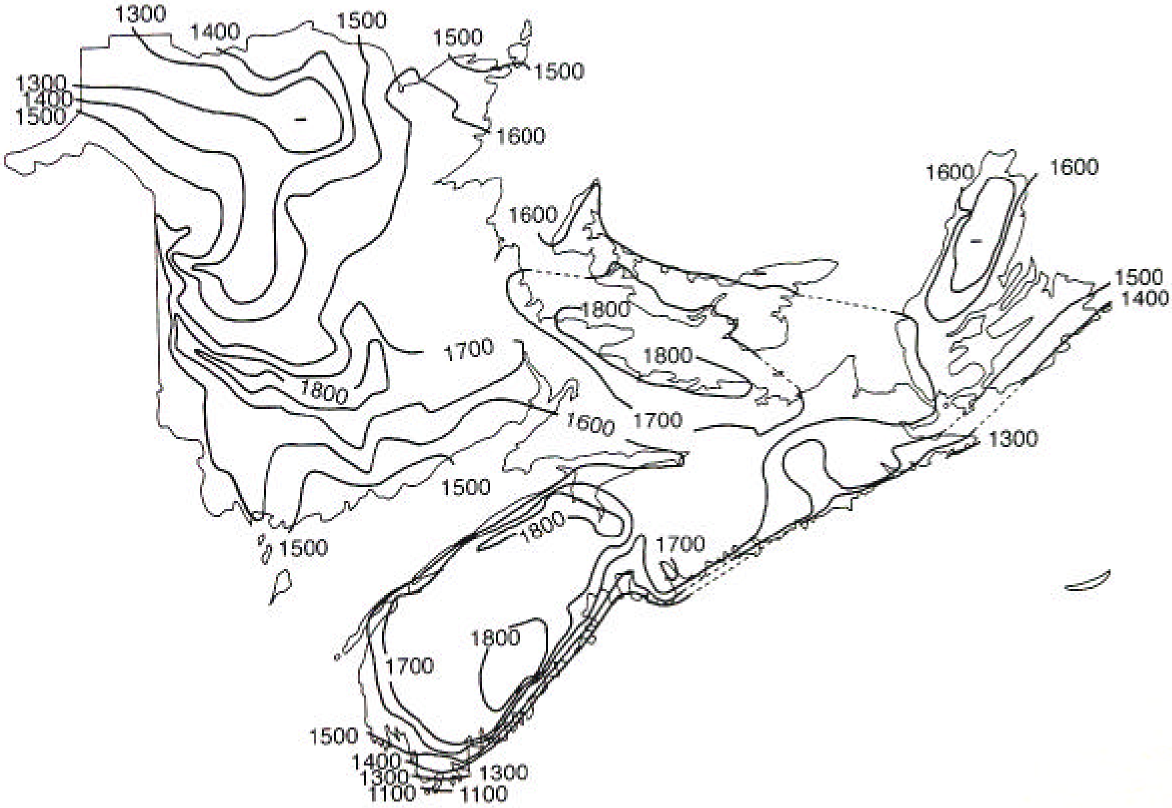

Fig. 6. GDD contours for the Maritime Provinces based on a threshold temperature of 5°C; after Gordon and Bootsma, (1993).

In the near future the digital format of this GDD map and its attribute files will be residing in the ARC/INFO system of the Fundy Model Forest, the Department of Natural Resources and Energy the Province of New Brunswick and the Canadian Soil Information System National Soils Data Base in Ottawa, Ontario, Canada.

Pedo-Climatic Map

A result of the merging or intersection of the GDD map and the forest soils of New Brunswick map is the Pedo-Climate map of New Brunswick, this map contains over one million individual polygons having 21,280 unique names. These maps and the map legend will take residence in the GIS of the Canadian Soil Information System (CanSIS) National Soil Data Base (NSDB), Ottawa, Canada, the Fundy Model Forest and New Brunswick Department of Natural Resources and Energy, Fredericton, NB, Canada.

An example of the map unit symbol is shown below:

CA03B2h

Where:
CA soil name (as per map legend)
03 drainage class (as per map legend)
B slope class (as per map legend)
2 aspect class (as per map legend ie, 1 = coldest, 2 = warmest, 3 = moderate)
h GDD class (as per map legend)

CanSIS-INTERPNB2000

The result of CanSIS-INTERPNB2000 application is four database attribute files (PAT, SMUF, SNF, SLF) which will take residence in the GIS of Canadian Soil Information System (CanSIS) National Soil Data Base (NSDB), Ottawa, Canada.

The pedo-climate map unit interpretation file (PCMUI) for agricultural crops and forest tree production are contained on a 3.5 inch floppy disk included in the back cover of this report. A total of 21280 unique map units listing comprise each file. The interpretation for tree production is included in FORPCMUINB2002.xls file and for agricultural crops is included in AGRPCMUINB2002.xls. The key to symbols are found in appendix 2.

INTERPRETATION OF SOIL MAP UNITS FOR VARIOUS USES

Soil survey interpretations are predictions of soil behaviour for specified land uses and management practices. They are only based on soil and site properties that directly influence the specified use of the land and should be considered a "best approximation". Soil map unit interpretations for some selected agricultural and forestry uses are listed in Appendix 2. The interpretive methods used are outlined below.

As soil-use interactions and implications become better known, new technologies may change the impacts of soils on crop yields and management practices. The interpretive ratings may also change, therefore, any discrepancies between the ratings listed here and those that may arise in the future are due to refinements in the interpretive algorithms and guidelines used in this report. The ratings provided in Appendix 2 are a sampling of some potential applications and are by no means a complete listing of all possible interpretations. The soils data presented in this report may be used to make better land use decisions for a much larger array of activities. Interpretations can also be made for:

- Urban development (roads, septic fields, basements, etc.)
- Recreation (picnic areas, trails, campsites, etc.
- Agricultural engineering uses (subsurface drains, sub-soiling, etc.)
- Source materials (round fill, sand, gravel, etc.)

* These interpretations are not reported in this report.

Soil maps remain useful long after the soil interpretations published with them have become outdated. It should also be noted that these interpretations are not recommendations, but rather are indications of potential difficulties, or conversely potential opportunities, that the land base offers to various uses. On-site investigation is required prior to any actual usage of the land.

1-Agricultural Interpretations Of Soil Map Units For Crop Production

In this section, the soil map units are interpreted for selected agricultural crops and forest treesof economic importance. Soil and site criteria were used to establish the suitability of each map unit for production of alfalfa, apples, spring cereals, winter cereals, forage, potatoes, balsam fir, white spruce, black spruce, red spruce, eastern white cedar, jack pine, red pine, white pine, sugar maple, white ash, yellow birch, and trembling aspen. The ratings for spring cereals are valid for barley, oats, and spring wheat while the rating for potatoes can also be applied to other similar vegetable crops. The interpretations are based on guidelines for crop suitability established in *Compendium of Soil Survey Interpretive Guides used in the Atlantic Provinces* (Atlantic Advisory Committee on Soil Survey 1987). These guidelines are Tables 2 to 7 and further summarized in Appendix 1. The soils are evaluated and placed into interpretive groupings, which are expressed in terms of suitability. These interpretations are listed in Appendix 2.

Four suitability classes are used:

Good (G) - The soil is relatively free of problems that hinder production and soil management, or the limitations that do occur can be easily overcome.

Fair (F) - Moderate soil and/or landscape limitations exist, but they can be overcome with good management and improvement practices or special techniques.

Poor (P) - Severe soil and/or landscape limitations exist which will be difficult and costly to overcome. Production is severely hindered and the efficacy of land improvement practices is low.

Unsuitable (U) - The inputs required to utilize or improve these soils for production is too great to justify under existing economic conditions.

The degree of soil suitability is determined by the most restrictive (least suitable) rating assigned to any of the rated soil properties. Soil, landscape and climate criteria are considered. Socio-economic factors such as nearness to municipal areas, market accessibility, size of area, etc..., are not taken into account. Organic soils (Bogs, Fens and Swamps) were not rated.

The major soil properties influencing use are also provided along with the degree of soil suitability:

- drainage or wetness (w)
- soil texture (x)
- thickness of friable soil (d)
- slope or topography (t)
- rockiness or bedrock exposures (r)
- stoniness (p)
- flooding or inundation (i)

These properties and the suitability class symbols used in Tables 1 to 6, are described in Appendix 3.

Table 2. Soil suitability for alfalfa

Major soil properties[1] influencing use	Good	Fair	Poor	Unsuitable
		Suitability class[1]		
Drainage (w)	W	R, MW	I	P, VP
Average texture[2] of friable soil (x)	l, sil, sl	cl, scl, si	ls, s, sc, sicl	c, sic
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>50	--	20-50[3]	<20
Slope class (t)	c, d	a, b, e	f	g, h
Rockiness (r)	R0	R1	R2	R3, R4, R5
Stoniness (p)	S0, S1, S2	S3	--	S4, S5
Flooding (i)	N	--	O	F, VF

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >20%.
[3] Upgrade to Fair if drainage is R, W, or MW.

Table 3. Soil suitability for apples

Major soil properties[1] influencing use	Good	Fair	Poor	Unsuitable
		Suitability class[1]		
Drainage (w)	W	R, MW	I	P, VP
Average texture[2] of friable soil (x)	l, si, sil, sl	ls, scl	cl, s, sc, sicl	c, sic
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>75	50-75	20-50	<20
Slope class (t)	a, b, c, d	e	f	g, h
Rockiness (r)	R0	R1	R2	R3, R4, R5
Stoniness (p)	S0, S1, S2	S3	--	S4, S5
Flooding (i)	N	--	O	F, VF

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >35%.

Table 4. Soil suitability for spring cereals

Major soil properties[1] influencing use	Good	Fair	Poor	Unsuitable
		Suitability class[1]		
Drainage (w)	W, MW	R, I	P	VP
Average texture[2] of friable soil (x)	l, si, sil, sl	cl, ls, scl, sicl	c, s, sc, sic	--
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>50	20-50[3]	--	<20
Slope class (t)	a, b, c	d	e	f, g, h
Rockiness (r)	R0	R1	--	R2, R3, R4, R5
Stoniness (p)	S0, S1, S2	--	S3	S4, S5
Flooding (i)	N	O	F	VF

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >20%.
[3] Upgrade to Good if drainage is W or MW.

Table 5. Soil suitability for winter cereals

Major soil properties[1] influencing use	Suitability class[1] Good	Fair	Poor	Unsuitable
Drainage (w)	R, W, MW	I	P	VP
Average texture[2] of friable soil (x)	l, sil, sl	ls, scl, si	cl, s, sicl	c, sc, sic
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>50	--	20-50[3]	<20
Slope class (t)	c	a, b, d	e	f, g, h
Rockiness (r)	R0	R1	--	R2, R3, R4, R5
Stoniness (p)	S0, S1, S2	--	S3	S4, S5
Flooding (i)	N	O	F	VF

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >20%.
[3] Upgrade to Fair if drainage is R, W, or MW.

Table 6. Soil suitability for forages

Major soil properties[1] influencing use	Suitability class[1] Good	Fair	Poor	Unsuitable
Drainage (w)	W, MW	R, I	P	VP
Average texture[2] of friable soil (x)	l, si, sil, sl	cl, ls, scl, sicl	c, s, sc, sic	--
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>20	--	--	<20
Slope class (t)	a, b, c, d	e	f	g, h
Rockiness (r)	R0	R1	--	R2, R3, R4, R5
Stoniness (p)	S0, S1, S2	S3	--	S4, S5
Flooding (i)	N, O	F	--	VF

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >35%.

Table 7. Soil suitability for potatoes

Major soil properties[1] influencing use	Suitability class[1] Good	Fair	Poor	Unsuitable
Drainage (w)	W, MW	R, I	P	VP
Average texture[2] of friable soil (x)	l, sil, sl	cl, ls, scl, si	sc, sicl	c, s, sic
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>40	20-40	--	<20
Slope class (t)	a, b, c	d	--	e, f, g, h
Rockiness (r)	R0	R1	--	R2, R3, R4, R5
Stoniness (p)	S0, S1, S2	S3	--	S4, S5
Flooding (i)	N	O	F	VF

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >20%.

2 - Forestry Interpretations Of Soil Map Units For Tree Production

In this section of the report the soil map units are interpreted for growth and operational limitations for selected forest tree species of economic importance. The inherent productivity or potential growth rate of forest tree species are determined by the interaction of physical, chemical, and biological factors that create a range of conditions of varying suitability for each species. The physical and chemical factors can be interpreted using soil and site criteria such as soil parent material lithology, inherent fertility, drainage, soil texture, depth of friable soil, slope, rockiness, and stoniness. These criteria are closely related to soil aeration, available moisture and nutrients, and depth and ease of root penetration, which in turn affect tree growth.

All tree species, without exception, show best growth on deep fertile moist sites. Growth rates tend to decrease as soil and site conditions deviate from this optimum. However, some species are more able to tolerate deficiencies than are other species. For example, jack pine is more tolerant of draughty conditions than sugar maple. The ability of the desired species to compete with undesirable species is another criterion related to soil/site suitability.

Soil drainage is probably the most important site factor affecting tree growth and forest productivity. Drainage pertains to the length of time it takes for water to be removed from the soil in relation to supply. Soil drainage is influenced by climate, topographic position, slope, aspect, soil texture and consistence, and depth to a restricting layer (compacted soil material or bedrock). Good drainage has beneficial effects on soil temperatures and aeration. Deeper rooting is promoted which in turn enhances access to nutrients and moisture.

Soils that have parent materials with a relatively high pH tend to support large and diverse populations of soil organisms. High levels of biological activity in soils enhance organic matter decomposition and the availability of nutrients for use by plants. The moist, cool climate of the Atlantic Region, by promoting rapid leaching of nutrients and slow replacement of freshly weathered products, is the basic reason for the acidity and relatively low fertility of the soils in the surveyed area.

Mineralogy or petrography origin of the soil materials is another determining factor in forest site nutrient status. The composition of parent rock materials contributes largely to the chemical characteristics and pH of soil. Some rock types are rich in bases and weather rapidly, resulting in soils with potentially high nutrient status. Other rocks contain few bases or are more resistant to weathering and release nutrients more sparingly. For a more detailed discussion on soils and plant nutrient supply in forestry refer to *Forest soils of New Brunswick* by Colpitts et al. (1995).

While natural or inherent fertility of the soil is to a large degree a function of soil mineralogy, it also relates to soil nutrient retention. Coarser-textured soils that are low in clay content tend to be more easily leached of nutrients than finer-textured soils. The inherent fertility rating is an estimate of the soil nutrient status based on the anticipated cumulative effects of the above listed factors.

Soil moisture (deficit/excess) and nutrient availability are most often the limiting factors in forest growth. Soil texture and depth of available friable soil material over a compact layer or bedrock are conditions which impact moisture and nutrient regimes. Slope, rockiness (bedrock exposures), and stoniness (surface stones) also affect moisture and nutrient availability but are more important in terms of site operability. Based on these considerations, the following key variables were identified for use in soil evaluation for forest production:

- drainage (w)
- inherent fertility (f)
- soil texture (x)
- depth of friable soil (d)
- slope (t)
- rockiness (r)
- stoniness (p)

Each soil (mapping) unit has been interpreted for its capability to support the growth of tree species common to the region: balsam fir (*Abies balsamea* (L.) Mill.) and white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) BSP.), eastern white cedar (*Thuja occidentalis* L.), jack pine (*Pinus banksiana* Lamb.) and red pine (*Pinus resinosa* Ait.), white pine (*Pinus strobus* L.), sugar maple (*Acer saccharum* Marsh.), white ash (*Fraxinus americana* L.), yellow birch (*Betula alleghaniensis* Britt.), and trembling aspen (*Populus tremuloides* Michx.). These interpretations are listed in Appendix 3.

Suitability classes were defined by relating the silvics of these major tree species to the key soil variables listed above. They are described in Tables 8 to 16 and further summarized in Appendix 1. Four classes of suitability were established to rate the selected species (cover types). They are described below. Class definitions were modified from those reported in the *Compendium of soil survey interpretive guidelines used in the Atlantic Provinces* (Atlantic Advisory Committee on Soil Survey 1987):

Good (G) - the soil has a good potential for tree growth and is relatively free of limitations that hinder forest production.

Fair (F) - the soil has a fair potential for tree growth and moderate soil/site limitations exist that hinder forest production. Limitations can be overcome with more intensive management practices.

Poor (P) - the soil has poor potential for tree growth and severe soil/site limitations must be overcome for satisfactory forest production. Limitations cause severe difficulties in harvesting, reforestation and/or forest management.

Unsuitable (U) - the soil is unsuitable for merchantable tree growth. Inputs required to utilize these soils/sites for tree production are too great to justify under existing economic conditions.

The degree of soil suitability is determined by the most restrictive (least suitable) rating assigned to any of the rated soil/landscape properties. It must be kept in mind that growth requirements and nutrient demands of tree species are distinctly different from those of most agricultural crops. Long periods of time, in excess of 40 years, are required for trees to reach merchantable size, and large variations in nutrient demand may occur over their life cycle. The intensive management practised on agricultural soils to enhance nutrient status is not feasible on forest soils. Organic soils were not rated for tree production.

Table 8. Soil suitability for production of balsam fir/white spruce

Major soil properties[1] influencing use	Good	Fair	Poor	Unsuitable
		Suitability class[1]		
Drainage (w)	W, MW	I	R, P	VP
Inherent fertility (f)	high	medium	low	very low
Average texture[2] of friable soil (x)	l, sil, scl	sl, cl, sicl	ls	s, sic, c
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>40	20-40	<20	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

Table 9. Soil suitability for production of black spruce

Major soil properties[1] influencing use	Good	Fair	Poor	Unsuitable
		Suitability class[1]		
Drainage (w)	W, MW	I, P	R, VP	--
Inherent fertility (f)	high, medium	low	very low	--
Average texture[2] of friable soil (x)	l, sil, scl	sl, cl, sicl	ls	s, sic, c
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>40	20-40	<20	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

Table 10. Soil suitability for production of eastern white cedar

Major soil properties[1] influencing use	Good	Fair	Poor	Unsuitable
		Suitability class[1]		
Drainage (w)	MW, I	W	P	VP, R
Inherent fertility (f)	high	medium	low, very low	--
Average texture[2] of friable soil (x)	l, sil, scl	cl, sicl	sl, sic, c	s, ls
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>40	20-40	<20	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

Table 11. Soil suitability for production of jack pine/red pine

Major soil properties[1] influencing use	Suitability class[1] Good	Fair	Poor	Unsuitable
Drainage (w)	W	MW, R	I	P, VP
Inherent fertility (f)	high, medium	low, very low	--	--
Average texture[2] of friable soil (x)	sl, ls	sil, l, scl	cl, sicl, s	sic, c
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>60	40-60	<40	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

Table 12. Soil suitability for production of white pine

Major soil properties[1] influencing use	Suitability class[1] Good	Fair	Poor	Unsuitable
Drainage (w)	W, MW	I	R, P	VP
Inherent fertility (f)	high, medium	low	very low	--
Average texture[2] of friable soil (x)	l, sil, sl, ls	scl, cl, sicl	s	sic, c
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>50	30-50	<30	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

Table 13. Soil suitability for production of sugar maple

Major soil properties[1] influencing use	Suitability class[1] Good	Fair	Poor	Unsuitable
Drainage (w)	W, MW	--	I, R	P, VP
Inherent fertility (f)	high	medium	low	very low
Average texture[2] of friable soil (x)	sl, l, sil	scl, cl, sicl	--	s, ls, sic, c
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>50	30-50	<30	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

Table 14. Soil suitability for production of white ash

Major soil properties[1] influencing use	Good	Suitability class[1] Fair	Poor	Unsuitable
Drainage (w)	W, MW	-	R, I, P	VP
Inherent fertility (f)	high	medium	low	very low
Average texture[2] of friable soil (x)	l, sil	sl, scl, cl, sicl	--	s, ls, sic, c
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>60	30-60	<30	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

Table 15. Soil suitability for production of yellow birch

Major soil properties[1] influencing use	Good	Suitability class[1] Fair	Poor	Unsuitable
Drainage (w)	W, MW	I	R, P	VP
Inherent fertility (f)	high	medium	low, very low	--
Average texture[2] of friable soil (x)	l, sil, sl	scl, cl, sicl	--	s, ls, sic, c
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>40	30-40	<30	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

Table 16. Soil suitability for production of trembling aspen

Major soil properties[1] influencing use	Good	Suitability class[1] Fair	Poor	Unsuitable
Drainage (w)	W	MW, I	R, P	VP
Inherent fertility (f)	high, medium	low	very low	--
Average texture[2] of friable soil (x)	sl, l, sil	scl, cl, sicl	ls	s, sic, c
Thickness (cm) of friable soil with BD <1.6 g/cm^3 (d)	>40	20-40	<20	--
Slope class (t)	a, b, c, d	e	f, g, h	--
Rockiness (r)	R0, R1	R2	R3	R4, R5
Stoniness (p)	S0, S1, S2	S3	S4	S5

[1] Soil properties and suitability class symbols are described in Appendix 3.
[2] Downgrade one class for coarse fragments >50%.

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APPENDIX 1

EXPLANATION OF MAJOR SOIL PROPERTIES INFLUENCING USE AND CORRESPONDING SYMBOLS USED IN TABLES 1 TO 15

Depth to bedrock (b) - Shallowness to bedrock limits the available rooting zone. It also has severe limitations on agricultural engineering activities such as subsurface drain tile installation, deep ripping, and farm road construction.

Depth of friable/permeable soil (d) - The thickness of friable soil material available for root growth and water percolation is an important consideration in crop production and land management. Dense compact subsoil layers resist penetration of plant roots and percolation of rainfall. These soils are also late to dry in the spring and easily saturated (perched zone of saturation) by high intensity or prolonged rainfall. Shallow rooting of crops may result in plant nutrient deficiencies, lack of resistance to mid-summer drought, and winter damage to legumes and winter cereals. Water percolation to subsurface drainage lines is also impeded. Soil layers with bulk densities (BD) greater than 1.60 g/cm^3 or permeabilities of less than 1.0 cm/hr, or both, are considered restricting layers.

Fertility (f) - Soil fertility is the quality of the soil that enables it to provide the proper balance of nutrients for plant growth. The soils of the map area were rated based on composition of parent material as follows:

Code	Soil name	Fertility_class	Code	Soil name	Fertility_class
ACD	Acadia	2	LAF	Lord and Foy	3
ACS	Acadia Siding	4	LAG	Lagaceville	4
ADD	Adder	4	LAV	Lavilette	4
AGC	Anagance	3	LGK	Long Lake	2
BAB	Barieau-Buctouche	3	LMD	Lomomd	4
BBA	Big Bald	4	LUZ	Lauzier	4
BBB	Babitt Brook	4	MAL	Martial	3
BBU	Babineau	3	MCK	Mckiel	4
BDC	Benedict	3	MET	Maliseet	3
BFU	Bellefleur	1	MGE	McGee	2
BGL	Big Hole	3	MID	Midland	4
BHG	Becaquimec	3	MMK	Muck	4
BHG	Becaguimec	3	MQT	Monquart	2
BIB	Britt Brook	2	MUI	Muniac	2
BIU	Barrieau	3	MUK	McClusky	4
BOB	Boston Brook	1	MUP	Mout Hope	3
BOG	Bog	4	MVC	Mafic Volcanic	3
BTL	Bottom Land	4	NKL	Nickle Mill	3
BUM	Buctouche	3	NKW	Nackawic	4
BUO	Blue Mountain	4	NSO	Nasson	3
BVG	Baie-Du-Vin-Glloway	3	OVK	Ogilvie Lake	4
BVN	Bais-Du-Vin	3	PAB	Parsons Brook	2
CAT	Carleton	1	PBQ	Penobsquis	4
CBU	Caribou	1	PEV	Parleeville	2
CGF	Carlingford	3	PND	Pinder	3
Code	**Soil name**	**Fertility_class**	**Code**	**Soil name**	**Fertility_class**
COH	Cornhill	2	PRY	Parry	2

CQU	Caraquet	3	PTA	Poitras	4
CTE	Cote	4	PTK	Portage Lake	3
CTR	Catamaran	2	PVT	Parleeville-Tobique	2
ERB	Erb Settelment	1	RCB	Richibucto	3
FEN	Fen	4	REC	Reece	2
FIS	Fair Isle	3	RGV	Rogersville	2
FMG	Flemming	1	RVK	Riverbank	3
FOR	Forston	4	RYO	Reily Brook	2
FUY	Fundy	3	SAD	St. Amand	3
FVF	Five Fingers	4	SAP	Saltspring	1
GAY	Geary	4	SBY	Sunbury	3
GFL	Grand Falls	4	SET	Serpentine	3
GGW	Gagetown	4	SGB	St.Gabriel	3
GLW	Galloway	3	SGS	Seigas	1
GMV	Guimond River	4	SIS	Sirois	3
GRD	Green Road	1	SKG	Skin gulch	3
GSV	Glassville	3	SMO	Salmon	3
GUQ	Gulquac	4	SNB	Stony Brook	3
GUV	Gurchville	4	SSX	Sussex	1
HMV	Holmsville	2	STQ	St.Quintin	4
HOU	Harcourt	3	SUY	Salisbury	2
HQU	Harquail	1	SWA	Swamp	4
IDK	Island Lake	4	TBQ	Tobique	2
ITV	Interval	1	TBU	Thibault	1
IVG	Irving	3	TCD	Tracadie	1
JDI	Jardine	1	TCU	Temiscouata	3
JEF	Jeffrie Corner	2	TCY	Tracy	2
JHV	Johnville	4	TDO	Tuadook	3
JKS	Jenkins	4	TFO	Trafton	4
JMK	Jummet Brook	4	TGC	Tetegouche	2
JQV	Jacket River	4	UCQ	Upper Caraquet	3
JUP	Juniper	3	UDI	Undine	1
KBG	Kouchibouquac	3	VCR	Victoria	2
KGC	Kingsclear	2	VIO	Violette	4
KGT	Kingston	2	WAS	Wasiss	3
KGV	Knightville	2	WHB	Washburn	4
KNC	Kennebecasis	3	WKF	Wakefield	2
KNT	Kimtore	4	ZMS	Mining Debrie	4
KWK	Kedgwick	1	ZOG	Organic Soil	4

* Key to fertility classes: 1 = high, 2 = medium, 3 = low, and 4 = very low
** The fertility ratings in this report are only used in soil map units interpretations for tree production.

Flooding or inundation (i) - Flooding occurs when water levels rise above normal stream, river, and lake boundaries.
Flooding interferes with time of planting, thus reducing an already short growing season. Erosion of unprotected bare ground, and subsequent sediment loading of stream courses, can also result. The following flooding classes are used:

None (N) - soils not subjected to flooding
Occasional (O) - soils subjected to flooding of short duration once every 3 or more years

Frequent (F) - soils subjected to flooding of medium duration once every 2 years
Very frequent (VF) - soils subjected to prolonged flooding every year
Stoniness (p) - Stoniness refers to the percentage of the land surface occupied by coarse fragments of stone size (>25 cm diameter).

Plowing, harrowing, and seeding equipment are significantly hindered by the presence of surface stones. Root crops, such as potatoes, are especially sensitive to stoniness, in terms of potential tuber injury. Alternately, stones are somewhat beneficial in terms of improving the soil thermal regime and protecting soil particles from being washed away. Classes of stoniness are defined on the basis of the percentage of the land surface occupied by stone fragments coarser than 25 cm in diameter:

Class	Effect on Cultivation	% Surface occupied	Distance apart (m)
S0	no hindrance	<0.01	>30
S1	slight hindrance	0.01-01	10-30
S2	some interference	0.1-3	2-10
S3	serious handicap to cultivation	3-15	1-2
S4	cultivation prevented until stones are cleared	15-50	0.1-1
S5	too stony to permit any cultivation	>50	<0.1

Rockiness (r) - Rockiness is an indication of the land surface area that is occupied by bedrock exposures. Bedrock exposures interfere with tillage. Bedrock outcrops are incapable of supporting viable crops and result in fields with non-uniform crop growth and quality. Rockiness classes are defined below:

Class	Effect on cultivation	% Surface occupied	Distance apart (m)
R0	no significant interference	<2	>75
R1	slight interference	2-10	25-75
R2	tillage of inter-tilled crops is impractical	10-25	10-25
R3	use of most machinery is impractical	25-50	2-10
R4	all use of machinery is impractical	50-90	<2
R5	---	>90	---

Slope or topography (t) - Slope steepness is an indication of the landscape gradient. Important practical aspects of soil slope that impact on use and management include: rate and amount of runoff; erodibility of the soil; use of agricultural machinery; and uniformity of crop growth and maturity. Although slope shape, length, and pattern also play an important role in slope effect, slope gradient is a convenient measure of slope impact on crop production and soil management. Slope classes are defined below:

<u>Slope class</u> <u>% slope</u>

a	0-0.5
b	0.5-2
c	2-5
d	5-9
e	9-15
f	15-30
g	30-45
h	45-70

Drainage or wetness (w) - Soil drainage refers to the rapidity and extent of the removal of water from the soil in relation to additions, especially by surface runoff and by flow through the soil to underground spaces. Persistence of excess water, especially in the spring and after prolonged or heavy precipitation, hinders seeding and harvesting machinery. Productivity of poorly drained soils is limited by a lack of aeration, susceptibility to compaction, and lower soil temperature. Soil drainage classes are described below:

Rapidly drained (R) - Water is removed from the soil rapidly in relation to supply. Soils are usually coarse-textured, shallow, or both. Water source is precipitation.

Well drained (W) - Water is removed from the soil readily but not rapidly. Soils are generally intermediate in texture and depth. Water source is precipitation.

Moderately well drained (MW) - Water is removed from the soil somewhat slowly in relation to supply. Soils are usually medium to fine textured. Precipitation is the dominant water source in medium- to fine-textured soils; precipitation and significant additions by subsurface flow are necessary in coarse-textured soils.

Imperfectly drained (I) - Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Precipitation, subsurface flow and groundwater act as a water source, alone or in combination. Soils have a wide range in texture and depth.

Poorly drained (P) - Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Subsurface flow or groundwater flow, or both, in addition to precipitation, are the main water sources. Soils have a wide range in texture and depth.

Very poorly drained (VP) - Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Groundwater flow and subsurface flow are the major water sources. Soils have a wide range in texture and depth.

Soil texture (u, x) - Soil texture is an indication of the relative proportions of the various mineral soil particle size groups - sand (2-0.05 mm), silt (0.05-0.002 mm) and clay (<0.002 mm). Each of the textural soil classes has an established range for percentage sand, silt, and clay. Soil texture is one of the most permanent characteristics of a soil, and probably the most important. Size of the soil particles affects most chemical, physical, and mineralogical reactions, and influences root growth for plants and engineering behavior for machinery operation. Soil texture influences: capillarity (water holding capacity); soil erodibility potential; cation exchange capacity and nutrient retention; percolation; trafficability; and soil tilth. Subsoil texture impacts on subsoiling success. Coarser-textured soil materials are more prone to shattering when subsoiled dry. Soil texture class abbreviations are defined below:

			Typical %	
Symbol	Soil texture	Sand	Silt	Clay
c	clay	28	22	50
cl	clay loam	32	35	33
l	loam	41	41	18
ls	loamy sand	82	12	6
s	sand	93	3	4
sc	sandy clay	52	7	41
scl	sandy clay loam	61	11	28
si	silt	9	86	5
sic	silty clay	7	46	47
sicl	silty clay loam	10	57	33
sil	silt loam	23	64	13
sl	sandy loam	65	25	10

APPENDIX 2

AGRICULTURAL INTERPRETATIONS OF SOIL MAP UNITS

Suitability for Crop Production of: Alfalfa, Apples, Spring Cereals, Winter Cereals, Forages, and Potatoes

G - Good - Relatively free of problems
F - Fair - Moderate soil and/or landscape limitations
P - Poor - Severe soil and/or landscape limitations
U - Unsuitable - Inputs required restrict use

w - drainage or wetness
x - average texture of friable soil
d - thickness of friable soil with BD <1.6 g/cm^3
t- slope or topography
r - rockiness
p - stoniness
i - flooding or inundation
cf- coarse fragments

***** Interpretation tables are included in the file **AGRPCMUINB2002.xls** on the 3.5 inch floppy contained on the back cover of this report.

FORESTRY INTERPRETATIONS OF SOIL MAP UNITS

Suitability forTree Production for: Balsam Fir/White Spruce, Black Spruce, Eastern White Cedar, Jack Pine/Red Pine, White Pine, Sugar Maple, White Ash, Yellow Birch, and Trembling Aspen

G - Good - Relatively free of problems
F - Fair - Moderate soil/site limitations
P - Poor - Severe soil/site limitations
U - Unsuitable - Inputs required are too great

w- drainage or wetness
f - fertility
x - average texture of friable soil
d -thickness of friable soil with BD<1.6 g/cm3
t - slope or topography
r - rockiness
p- stoniness
cl- climate GDD
cf- coarse fragments
i- inundation

***** Interpretation tables are included in the file **FORPCMUINB2002.xls** on the 3.5 inch floppy contained on the back cover of this report.