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Climatic zonation for forage crops in the Atlantic Region

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Climatic zonation for forage crops in the Atlantic Region

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Zonage climatologique pour la culture des plantes fourragères
dans la région de l'Atlantique

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SUMMARY

This bulletin describes the spatial variation of several derived climatic parameters of importance to forage crop production and management in the Atlantic Provinces. Accumulated growing degree-days above 5°C (GDD) in spring are used to estimate important maturity stages in several forage species for first cut. GDD's remaining in the fall are used to indicate probable variation in the critical fall period during which alfalfa and possibly other species susceptible to winterkill should not be harvested. The length of season between specified GDD's accumulated in spring and remaining in fall is used as a criterion for designating variation in suitable cutting frequencies of forages. Simplified moisture criteria based on rainfall and estimated potential evapotranspiration are used to describe regional differences in hay-making conditions and in the likelihood of moisture stress during summer months.

RÉSUMÉ

Dans le présent compte rendu, nous décrivons la variation en fonction de l'espace de plusieurs paramètres climatiques influant sur la production et la régie des cultures fourragères dans les provinces de l'Atlantique. D'après le nombre total de degrés-jours de croissance au-dessus de 5°C (D.J.C.) accumulés au printemps, on a estimé à quel moment les cultures de plusieurs espèces fourragères sont parvenues au stade de maturation crucial pour la première récolte. Les D.J.C. qui restent en automne indiquent la variation probable de la période critique automnale durant laquelle la luzerne et certaines autres espèces sensibles au froid d'hiver ne devraient pas être récoltées. La longueur de la période entre la date au printemps où un nombre précis de D.J.C. sont accumulés et la date en automne où un nombre précis de D.J.C. restent à venir sert de critère pour déterminer la variation de la fréquence appropriée des récoltes de plantes fourragères. Pour décrire les variations régionales des conditions de fenaison et des risques de pénurie d'eau durant l'été, on se sert de critères d'humidité simplifiés, basé sur l'abondance des précipitations et la valeur approximative de l'évapotranspiration potentielle.

1. INTRODUCTION

The climatic analyses described in this bulletin were undertaken in response to a need to divide the Atlantic region into different zones for the purpose of making specific recommendations on forage crop production and management. Climate has an important effect on the adaptability of various forage species and cultivars to the region. Conditions permit a wide variety of forage crops to be grown (Atlantic Field Crops Committee 1980). While timothy is the most widely grown forage grass, other species such as orchardgrass and bromegrass are also being cultivated. Legumes such as alfalfa, clover, and birdsfoot trefoil are also grown, but successful production depends upon good winter survival. In recent years annual ryegrass has also increased in popularity as a source of feed. Although there are many factors which affect production and management of forage crops, climate is one of the most important. The climate not only affects growth patterns, persistence, quality and yield, but also influences the response of each cultivar to different management practices.

This study focuses on four main areas in which climate has a significant influence. These areas are (i) the time when optimum maturity for first harvest is reached, (ii) the critical fall period when alfalfa should not be harvested for good management, (iii) the harvest frequency and yield of forage crops as influenced by season length and, (iv) hay-making conditions and soil water deficits during the summer period.

(i) The time when forage crops reach specific stages of maturity is an important factor in production of high quality forages in the Atlantic region. Research has demonstrated that grasses must be harvested at early heading and legumes no later than early flowering to achieve maximum yield of digestible nutrients (Atlantic Field Crops Committee, 1980). It has also been shown that the harvest season for timothy can be spread out by planting cultivars that grow and develop at different rates and in this way allow the crop to be cut at the optimum stage of growth (Grant and Burgess, 1978). The date that a particular cultivar will reach the required stage of maturity will vary depending mainly upon climatic conditions in the region where it is grown. In this study, the average dates when cultivars of alfalfa, timothy, and red clover reach specific stages of maturity for first cut are estimated on the basis of accumulated growing degree-days above 5°C (GDD) in each area.

(ii) The probable variation in the critical fall period during which alfalfa should not be harvested is also examined. Alfalfa must be hardened during the fall period to aid survival over winter in many parts of North America. Grazing or cutting of alfalfa should be avoided for approximately six weeks in the fall because defoliation during this period will interfere with the hardening process and will increase the chance of winter injury (Fulkerson, 1974; Gottfred, 1980; Heinrichs, 1969; Woolley and Wilsie, 1961). The period required for alfalfa to attain adequate cold resistance will vary depending upon climatic conditions. Fulkerson (1970) found that in southern Ontario, the harvest date which resulted in the greatest decline in alfalfa yields coincided closely with the 25 percent risk date of frost in each region. Management recommendations advise farmers in Ontario not to cut alfalfa for a six week period centred around this critical fall harvest date (Ontario Field Crops Research Committee, 1981). Woolley and Wilsie (1961) questioned the validity of using the first killing frost to determine the date of fall removal, and proposed a system of cold unit accumulation based on soil temperature to determine time required for adequate hardiness. In the Atlantic region of Canada, it has been observed that alfalfa harvested or grazed in the previous fall sustained more winter injury (MacKenzie and Suzuki, 1978; Suzuki and McRae, 1979; Willis and Suzuki, 1971). Although proper management does not guarantee successful winter survival, it will reduce the risk of winter injury. Therefore, crop recommendations state that alfalfa should not be cut or grazed between September 1 and October 15 (Atlantic Field Crops Committee, 1980). In this study, the critical fall period during which alfalfa should not be harvested was defined on the basis of accumulated GDD remaining in the fall. This was considered a suitable criterion since experience in other regions has shown that the critical harvest period is advanced in areas which experience an earlier decline in temperature in autumn (Fulkerson, 1970; Woolley and Wilsie, 1961).

(iii) The frequency of harvesting and the potential yield of several forage species are related to the number of days between the time when 350 GDD are accumulated in spring and 450 GDD are remaining in fall. This criterion is based on the assumption that temperature is a prime limiting factor in growth in spring and fall, while during summer months growth is mainly a function of time and less influenced by temperature (assuming no severe moisture stress). Potential yield in this study is defined as the yield which can be achieved with good management under present technology, as approximated by yields recorded at research station trials in the region in years with relatively good winter survival.

(iv) The Atlantic region usually receives sufficient rainfall to maintain crop growth during summer months. Nevertheless, in some years, moisture stress significantly retards the growth of forages (Atlantic Field Crops Committee, 1975; Black, 1978; Calder and Nicholson, 1970). Regrowth after defoliation during summer months is affected most often since moisture stress is most likely during this period. For example, dry summer weather in Prince Edward Island in 1975 prevented a second cut of timothy and reduced the yield of the second cut of alfalfa by at least fifty percent (Atlantic Field Crops Committee, 1975). A surplus of moisture in summer may also be detrimental to forage production in some years or regions. Black (1978) observed that an excessive moisture supply caused a decline in pasture production, possibly due to waterlogging of soils and leaching of nutrients. More importantly, excess moisture during the haying season can result in a serious decline in hay quality by delaying the harvest past the time when the forage crop is at its optimum maturity. Wet weather also causes a serious decline in both the quantity and quality of forages after cutting (Wilkinson, 1981). The above evidence confirms the importance of moisture status during summer months in forage zonation. In this study, spatial variations in indices of hay-drying conditions and soil water deficits are analyzed, based on potential evapotranspiration estimates and rainfall for the period of June through August. Moisture deficits are a function of climate (rainfall, evaporation), soil (water holding capacity, drainage) and crop characteristics (transpiration, rooting habit, drought resistance). Information is incomplete on the relationship between all these factors in the Atlantic region and therefore simplifying assumptions were made in the analyses.

This bulletin describes in detail the methods used to assess the spatial distribution of climatic parameters recognized as being important to forage production and also presents the results of the analyses. The information will help agronomists formulate forage production and management recommendations for the region. The results also have significance for land evaluation and assessment of crop production potential. Maximum benefit will be achieved if the climatic information is integrated with data on soils in the region.

2. METHODOLOGY

2.1 Estimating maturity dates for first cut

There is very little information available in the literature on suitable methods for predicting stages of maturity in forage crops, even though the influence of temperature on development of grasses and legumes has been investigated extensively (Knight and Hollowell, 1958; Kozumplik and Christie, 1972; Pearson and Hunt, 1972; Smith and Jewiss, 1966). Most studies have demonstrated that, except for extremely high temperatures, the rate of development to maturity increases with increasing temperature. Factors such as moisture, fertility, and daylength may influence the rate of development to some extent. However, under cool, moist conditions typically experienced during spring in the Atlantic region, temperature is the most important factor determining when stages of maturity will be reached. Selirio and Brown (1979) used an accumulation of 550 GDD as an estimate of the time when alfalfa reaches the flowering stage in southern Ontario. Comparison of accumulated GDD with crop maturity stages recorded in forage trials conducted by the Atlantic Advisory Committee on Forage Crops indicated that in the Atlantic Region, the early bloom stage of Saranac and Iroquois alfalfa in post-seeding years is reached when approximately 450 GDD have accumulated (Bootsma, unpublished observations). While the early alfalfa cultivars such as Saranac exhibit more rapid growth in spring than medium cultivars such as Iroquois, most cultivars reach maturity at approximately the same time. The data also indicate that Champ timothy reaches the 50 percent heading stage when approximately 450 GDD have accumulated. Clair timothy reaches 50 percent heading about 50 to 70 degree-days sooner than Champ, and Climax is about 50 to 70 degree-days later. Clair, Champ, and Climax are timothy cultivars recommended for production in the region that are rated as very early, early, and medium maturity respectively. Double cut red clover cultivars Ottawa and Lakeland reach the early bloom stage when about 450 GDD have accumulated.

Considerable variation in the degree-day requirement between seasons and locations indicates a need to develop a more accurate method of predicting maturity. For example, alfalfa grown at St. John's, Newfoundland, tends to require fewer heat units to reach the early bloom stage than alfalfa grown at warmer Maritime locations. In some years and at some locations there is also more spread in maturity dates and degree-day requirements between varieties than in other years or at other locations. In the absence of an alternative method, the accumulated degree-day values listed in Table 1 were used to estimate maturity stages in timothy, alfalfa and red clover in spring. These values may need to be adjusted in future when more data from experimental plots becomes available.

Table 1. Estimated growing degree-day requirements for specific maturity stages in several forage crops

Accumulated growing degree days above 5°C (GDD)	Approximate stage of maturity in post-seeding years				
			timothy		
	alfalfa*	red clover**	Clair	Champ	Climax
350	early bud	-	early head	-	-
400	late bud	-	50% head	early head	-
450	early bloom	early bloom	full head	50% head	early head
500	-	-	-	full head	50% head

* average based on Saranac and Iroquois cultivars.
**average based on Lakeland and Ottawa cultivars.

Average dates when maturity stages in Table 1 are reached in the Atlantic region were estimated by determining the average date when 350 and 450 GDD have accumulated, using the following quadratic regression equations:

$$Y_1 = 126.72 - 12.527\,X_1 + 0.3077\,X_1^2 \qquad (1)$$

$$Y_2 = 140.11 - 13.201\,X_1 + 0.3354\,X_1^2 \qquad (2)$$

where Y_1 and Y_2 are the average dates when 350 and 450 GDD respectively have accumulated in spring (June 1 = 1);
X_1 is the mean air temperature for May and June (°C).

Temperature normals for the 1951-1980 period (Environment Canada, 1982) were substituted into these equations to estimate Y_1 and Y_2 at 231 climatic stations in the region. Temperature normals for stations with less than 20 years of records were previously adjusted to the 30-year normal period by Environment Canada using standard techniques.

Equations (1) and (2) were determined by multiple linear regression analyses using data from 68 climate stations in the Atlantic region for the 1941-1970 normal period (Environment Canada, 1971). Both equations had a coefficient of determination (r^2) of 0.984 and standard error of estimate (s.e.) of 1 day. In developing these equations, accumulated GDD were determined from a graph of monthly mean air temperature for each station by summing daily GDD values. A regression equation was used to correct GDD sums based on the graphs for months with less than 200 GDD as follows:

$$Y_C = 19.98 + 0.904\,Y_G \qquad (3)$$

where Y_C is the corrected monthly GDD summation;
Y_G is the monthly GDD sum determined from the mean temperature graph.

Equation (3) was developed using monthly GDD published by Environment Canada (Treidl, 1978) for Y_C, since these were calculated from daily maximum and minimum air temperatures. Data from 23 station-months yielded an r^2 value of 0.99 and an s.e. of 6.5 GDD. This method of correcting GDD sums calculated from mean air temperatures proved to be as accurate but simpler than Thom's method (1966). A correction factor shown in Figure 1 was also applied for months with zero GDD but with mean temperatures above 1°C. Figure 1 was determined from comparisons of mean monthly air temperature with GDD published by Environment Canada for station months having zero GDD based on the graph method.

The accuracy using the graph method with corrections to determine dates when 350 GDD and 450 GDD have accumulated was further checked by comparison with data published by Environment Canada (Treidl, 1979) for 36 locations. Weekly GDD summations by Environment Canada were interpolated to derive the 350 and 450 GDD dates. The results of these two methods were highly correlated (r = 0.996) and were generally within 1 day of each other, indicating that the graph method was sufficiently accurate for the purpose of this study.

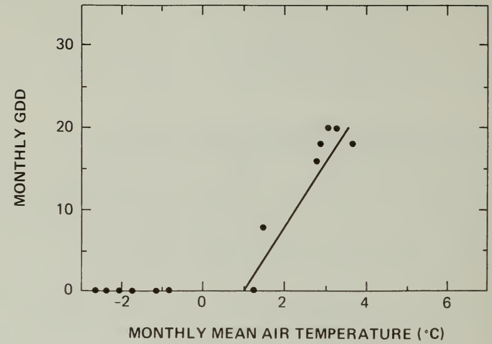

Fig. 1 Correction factor for monthly growing degree-days above 5°C (GDD) in spring.

2.2 Estimating the critical fall harvest period for alfalfa

The critical fall period during which alfalfa should not be harvested was defined as the 45-day period beginning on the date when an average of 450 GDD were still remaining in the fall. This criterion was considered appropriate since periods were found to coincide with the critical harvest period presently recommended for the Atlantic region (Atlantic Field Crops Committee, 1980) for locations where alfalfa field trials have been regularly conducted (Charlottetown, Nappan, Truro). Furthermore, periods thus defined were centred near the 25 percent risk date for frost in inland areas of New Brunswick and Nova Scotia, which corresponded closely with the relationship between the critical harvest date (midpoint of the critical harvest period) and frost risk in Ontario (Fulkerson, 1970). In coastal regions, this period was centred considerably earlier than the 25 percent risk date due to the moderating influence of ocean waters on night-time temperatures. The criterion may need to be modified in future when more information becomes available on the effect of cutting management on winter survival in the Atlantic region.

A method similar to that used for estimating GDD in spring was used to calculate the average date when 450 GDD were remaining in the autumn. Normal temperature data for the 1951-1980 period (Environment Canada, 1982) were used from 232 climate stations in the following regression equation:

$$Y_3 = -43.34 + 6.317\ X \qquad (4)$$

where Y_3 is the date when 450 GDD are remaining in the fall(August 1 = 1);
X is the mean air temperature for September and October (°C).

Equation (4) was determined by linear regression analyses using data from 68 stations in the region for the 1941-1970 normal period (Environment Canada, 1971). This equation had an r^2 value of 0.98 and an s.e. of 1 day. Various combinations of average temperature were tried along with quadratic terms, but these did not significantly improve the accuracy of the regression relationship. The 450 GDD date (Y_3) was determined from normal temperature graphs by accumulating daily GDD values backwards in time from the date when the mean temperature curve dropped below 5°C. Similar methods were employed to correct GDD summations as with the spring data. The regression equation used to correct GDD sums for months with less than 220 GDD was:

$$Y_C = 24.03 + 0.894\ X_G \qquad (5)$$

where Y_C is the corrected monthly GDD summation;
Y_G is the monthly GDD determined from the mean temperature graph.

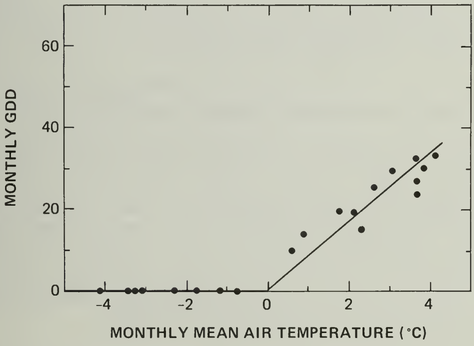

Fig. 2 Correction factor for monthly growing degree-days above 5°C (GDD) in autumn.

Equation (5) was determined by using monthly GDD summations published by Environment Canada (Treidl, 1978) for Y_C, similar to equation (3) for the spring. Data from 26 station-months yielded an r^2 value of 0.99 and a s.e. of 6.2 GDD. Figure 2 shows the correction factor used for months with zero GDD based on the mean temperature graphs, but which have mean temperatures above 0°C. This figure is comparable to Figure 1 for the spring data.

The accuracy with which the graph method estimated the date when 450 GDD remain in fall was evaluated by comparison with dates determined from interpolating weekly GDD summations published by Environment Canada (Treidl, 1979) for 36 stations. Dates determined from Environment Canada data were assumed to be correct values since these GDD summations were based on daily maximum and minimum air temperatures. The graph method with corrections applied yielded dates which were generally 1 to 3 days earlier than dates based on Environment Canada data. The following regression equation describes the relationship between dates determined by these two methods:

$$Y_A = 2.96 + 0.954\, X_G \qquad (6)$$

where Y_A is the date when 450 GDD are remaining in fall based on Environment Canada data;

X_G is the date determined using normal temperature graphs with corrections applied.

Equation (6) had an r^2 of 0.97 and a s.e. of 1.3 days. Estimates of the 450 GDD date in the fall for all 232 stations in the region were adjusted by using the value of Y_3 in equation (4) for X_G in equation (6). These adjusted values were taken as the starting date of the 45-day period during which alfalfa should not be harvested.

2.3 Zonation criterion for harvest frequency and potential yield

Sections 2.1 and 2.2 describe procedures used to estimate when 350 GDD have accumulated in spring and when 450 GDD are remaining in fall in an average year. The number of days between these two dates (DAYS) was calculated and used as a zonation criterion for the frequency of harvest and potential yield of various forage species. The rationale for using this criterion was partly discussed in the introduction. In each particular region, perennial forage crops have available for growth the number of days given by this parameter plus an additional 800 GDD (in spring and fall). For alfalfa, the parameter DAYS represents the time available for regrowth for early cultivars after the first cut until the critical fall period when harvesting should be avoided.

2.4 Zonation criteria for drying index and water deficits

The relative potential for curing hay in the field in various parts of the Atlantic region was assessed by using a drying index developed from field experimental data by Hayhoe and Jackson (1974). The index was defined as

$$I = PE - 0.2\ P \qquad (7)$$

where PE is the potential evaporation (mm);
P is the precipitation (mm);
I is the index value.

Equation (7) can be used to obtain daily values of I or an accumulated value over a given number of days. For the purpose of this study, the accumulated value from June through August was calculated for over 230 stations using temperature and precipitation normals for the 1951-1980 normal period (Environment Canada, 1982). Total PE was estimated using an equation developed by Baier and Robertson (1965) and the conversion factor determined by Baier (1971) as follows.

The average daily latent evaporation (LE) in cm^3 for the period June to August was calculated by the equation,

$$LE = -57.334 + 1.6704\ TMAX + 1.6794\ TRANGE + 0.0486\ Q_o \qquad (8)$$

where TMAX is the average daily maximum temperature from June through August (°C);
TRANGE is the average difference in °C between the daily maximum and daily minimum temperature for the same period;
Q_o is the average total solar radiation at the top of the atmosphere over the same period (cal cm^{-2} day^{-1})

Q_o was estimated from station latitude (LAT) using:

$$Q_o = 934.4 + 3.6308\ (52.0 - LAT)^{0.927} \qquad (9)$$

for latitudes between 43°N and 51.5°N, and

$$Q_o = 907.3 + 4.1759\ (59.0 - LAT)^{0.970} \qquad (10)$$

for latitudes above 51.5°N and less than 59°N.

In the development of Equations (9) and (10), Q_o was calculated at specific latitudes using daily values of solar radiation at the top of the atmosphere determined using the method described by Robertson and Russelo (1968). Both equations had an r^2 value exceeding 0.99.

LE values from equation (8) were converted to total PE in mm from June through August by the formula

$$\text{Total PE} = LE \times 0.086 \times N \qquad (11)$$

where N is the total number of days in the period.

For convenience, the drying index I was normalized to a maximum of 100 by the following formula:

$$I_N = \frac{I \times 100}{I_{MAX}} \qquad (12)$$

where I_N is the normalized index;
I is the original drying index calculated from Equation (7); and
I_{MAX} is the maximum value of the drying index, taken as 360 mm.

Water deficit zonation was accomplished by using modifications of water balance procedures described in detail by Thornthwaite (1948) and Thornthwaite and Mather (1957). Thornthwaite defined moisture deficit as the amount by which potential exceeds actual evapotranspiration in any month. Calculations are time consuming and require knowledge of the soil water holding capacity (WHC).

In this study, water deficits were calculated for three WHC's (50, 100 and 200 mm) using relationships between seasonal water deficits and Accumulated Potential Water Loss (APWL) shown in Figure 3. Thornthwaite and Mather (1957) defined APWL as the sum of all negative monthly values of P-PE. In this study, APWL is defined as the sum of all positive values of PE-P for convenience. The relationships in Figure 3 were based on Thornthwaite water balance tabulations for selected stations in the Atlantic provinces and Ontario by Phillips (1976). However, Phillips only calculated water deficits for 100 and 200 mm WHC. The graph for 50 mm WHC was constructed by calculating water deficits following Thornthwaite's procedures (Thornthwaite and Mather, 1957).

APWL's were calculated for 232 climate stations in the region using total precipitation and PE values for the months of June through August for the 1951-1980 normal period (Environment Canada, 1982). This procedure was valid since in most cases, PE-P was positive or near zero for these months only. PE was estimated by the same procedure as previously described for the drying index, rather than by the Thornthwaite method. Thornthwaite's procedure overestimated PE in coastal areas of the Atlantic region because it is based on mean temperature and does not account for differences in relative humidity or vapour pressure deficit. The formula of Baier and Robertson (1965) accounts for humidity differences to some extent, since coastal areas with mean temperatures comparable to inland locations have lower PE values due to smaller day/night temperature ranges. PE estimates using the Baier and Robertson formula were as much as 20 per cent higher than Thornthwaite PE for some stations. For this reason, data from selected stations in Ontario (Phillips, 1976) were used to determine the relationship between APWL and water deficits in Figure 3 at these higher PE values.

Water deficits were calculated using equations fitted to the graphs in Figure 3. Best results were achieved by using two equations for each of the curves as shown in Table 2.

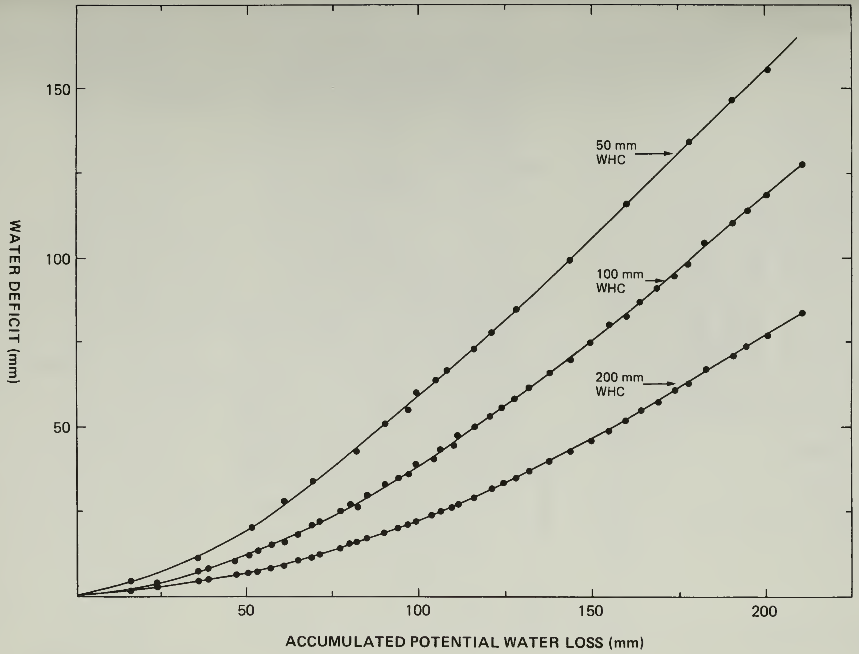

Fig. 3. Relationship between Thornthwaite Water Deficit and Accumulated Potential Water Loss at three soil water holding capacities.

Table 2. Equations for calculating water deficits (WD) from Accumulated Potential Water Loss (APWL)

WHC[*1] (mm)	APWL[*2] range (mm)	Equation used to estimate water deficits
50	0-70	$WD = 0.404 + 0.11351\ AWPL + 0.005220\ (APWL)^2$
50	>70	$WD = -16.658 + 0.6520\ APWL + 0.0010685\ (APWL)^2$
100	0-150	$WD = 0.01697\ (APWL)^{1.67581}$
100	>150	$WD = 0.85338\ APWL - 52.776$
200	0-150	$WD = 0.0061224\ (APWL)^{1.78276}$
200	>150	$WD = 0.61737\ APWL - 46.222$

[*1] WHC - water holding capacity of the soil.
[*2] APWL - accumulated potential water loss.
NOTE: For APWL ≤ 0.0, WD = 0.0.

2.5 Mapping procedures

Criteria previously described were determined for approximately 232 climatic stations in the Atlantic region. Results were plotted on maps of the region and isolines connecting points of equal value were drawn. Major topographic features such as the Annapolis and Saint John River valleys were considered when drawing isolines. Data from climate stations in Quebec and Maine were used to help position isolines of the criteria described in sections 2.1, 2.2 and 2.3 in the vicinity of the borders. Adjustments were also made to account for biases in these same criteria at first order hourly synoptic stations in the region. These biases are due to different observational procedures with respect to the climatological day for minimum temperature at synoptic and ordinary climate stations (Bootsma, 1976). For example, a bias in the monthly mean air temperature at stations with hourly observations could delay estimated spring maturity dates (section 2.1) by as much as 5 days. Where discrepancies were evident, more weight was given to ordinary climate stations than to first order stations in the mapping procedure.

3. RESULTS AND DISCUSSION

A general map of the Atlantic region which identifies the locations referred to in the text is shown in Figure 4. The province of Newfoundland was mapped at a considerably smaller scale than the other three Maritime provinces. A list of climatic stations used in this study and calculated values for designated criteria are given in the Appendix. The approximate locations of the climatic stations are identified in the Appendix in Figure 10.

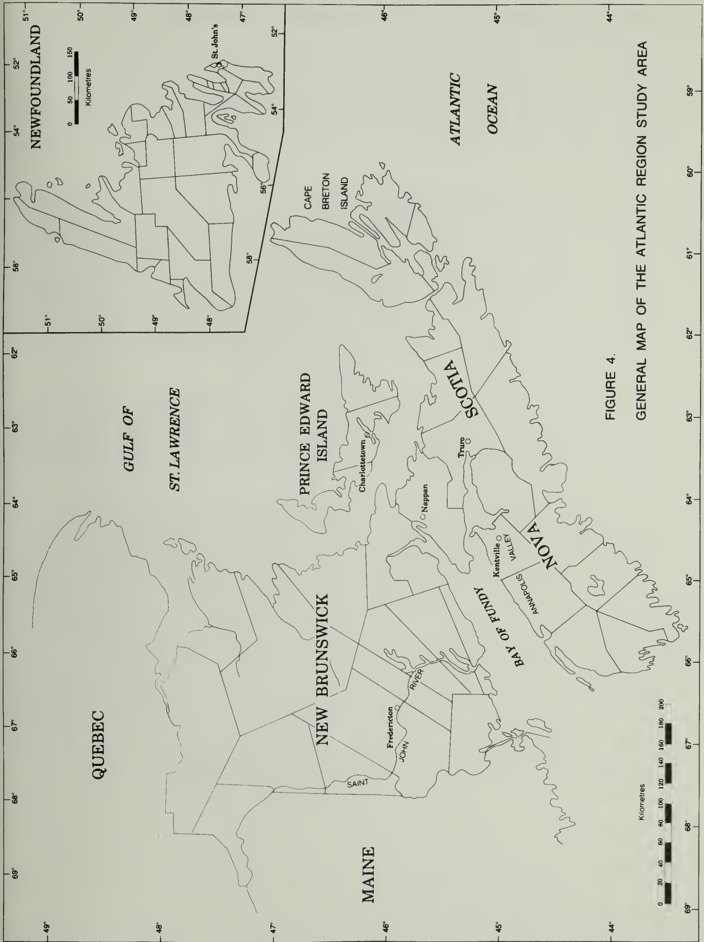

FIGURE 4.

GENERAL MAP OF THE ATLANTIC REGION STUDY AREA

3.1 Heat unit zonation for estimating optimum first harvest date

Since isoline patterns for the dates when 350 GDD and 450 GDD have accumulated in spring as determined from equations (1) and (2) were similar, one zonation map could be drawn for the region (Figure 5). The 450 GDD date was generally 10 days later than the 350 GDD date. The average dates when 350, 400 and 450 GDD have accumulated in each zone in Figure 5 are given in Table 3. The 400 GDD dates were derived by interpolation.

The date when 350 GDD have accumulated in spring varied from before June 15 in the Annapolis and Saint John River valleys to as late as the last week in July in some parts of Newfoundland. The 350 GDD date corresponds to the date when Saranac and Iroquois alfalfa are estimated to reach the early bud stage in an average year in each region. This represents the earliest possible date for the first cut if a maximum period of regrowth is desired for additional harvests later in the season. Alfalfa cut on this date would have higher digestibility and protein content than if cut at 450 GDD, but lower dry matter yields (Atlantic Field Crops Committee, 1980). Clair timothy is also expected to be at the desirable maturity stage for first cut on this date.

The date when 450 GDD have accumulated in spring varies from before June 25 in the Annapolis and Saint John River valleys, to as late as the first week in August in some areas of Newfoundland. This date corresponds approximately to the optimum date of first cutting of Climax timothy and double cut red clover cultivars, and the latest desirable cutting date of alfalfa.

The data presented are based on expected heat unit accumulations in a normal year. Variation in maturity will occur from season to season depending on weather conditions. Within each zone there will also be variability in heat units available to the crop due to differences in soil and in microclimate. For example, forages grown on cool, wet soils which are slow to warm up in spring will mature later than those grown on warmer soils although yields may be higher on the former. Field exposure will also affect the accumulation of heat units, and good shelter due to windbreaks and/or topography can advance maturity considerably. Weather stations are usually located on fairly well-exposed sites and the zonation map should be quite representative of this type of condition. The map should be helpful in formulating recommendations on suitable harvesting dates for the first cut of forage crops in each area of the Atlantic region. However, growers will need to base their decision on when to actually take the first cut on the observed stage of maturity as it is influenced by local environmental conditions and management.

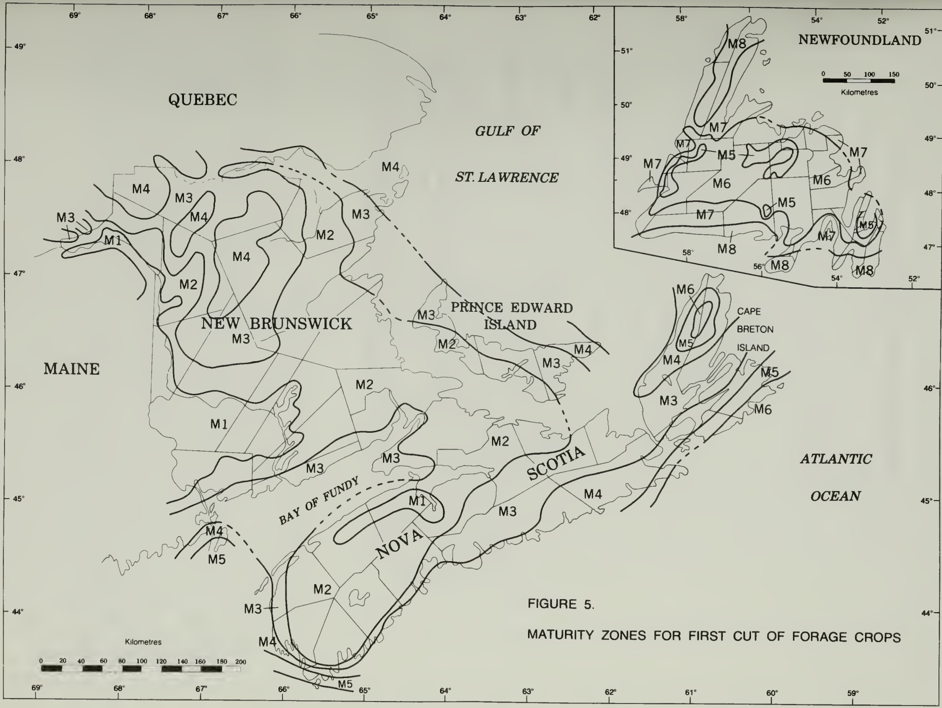

FIGURE 5.

MATURITY ZONES FOR FIRST CUT OF FORAGE CROPS

Table 3. Average dates of accumulated growing degree-days (GDD) for maturity zones in Figure 5

Zone	Average dates when GDD have accumulated		
	350 GDD*1	400 GDD*2	450 GDD*3
M1	June 15 or earlier	June 21 or earlier	June 25 or earlier
M2	June 16-20	June 22-26	June 26-30
M3	June 21-25	June 27-Jul 1	July 1-5
M4	June 26-30	July 2-6	July 6-10
M5	July 1-5	July 7-11	July 11-15
M6	July 6-15	July 12-21	July 16-25
M7	July 16-25	July 22-31	July 26-Aug 4
M8	July 26 or later	Aug 1 or later	Aug 5 or later

*1 Estimated average date when alfalfa in early bud and Clair timothy in early head stage.

*2 Estimated average date when alfalfa in late bud stage, Clair timothy in 50% head and Champ timothy in early head stage.

*3 Estimated average date when alfalfa and double cut red clover in early bloom, Champ timothy in 50% head and Climax timothy in early head stage.

Note: Alfalfa refers to the cultivars Saranac and Iroquois; red clover refers to the cultivars Lakeland and Ottawa.

3.2 Critical fall harvest period for alfalfa

The average date when 450 GDD remain in the fall as determined by equations (4) and (6) was used to construct the zonation map shown in Figure 6. Since the 450 GDD date was taken as the beginning of a 45-day period during which alfalfa should not be harvested, it was possible to define a critical fall harvest period for each zone as shown in Table 4. The estimated starting date of the critical period ranged from as early as August 5 in northwestern New Brunswick to as late as September 5 in some of the coastal regions in southwestern Nova Scotia. In most of the agricultural areas within the region, the estimated starting dates ranged between August 21 and September 4 (zones F5 to F7). In Labrador, the date when 450 GDD remain in fall ranged from as early as July 10 in the north to after July 25 in the southeast.

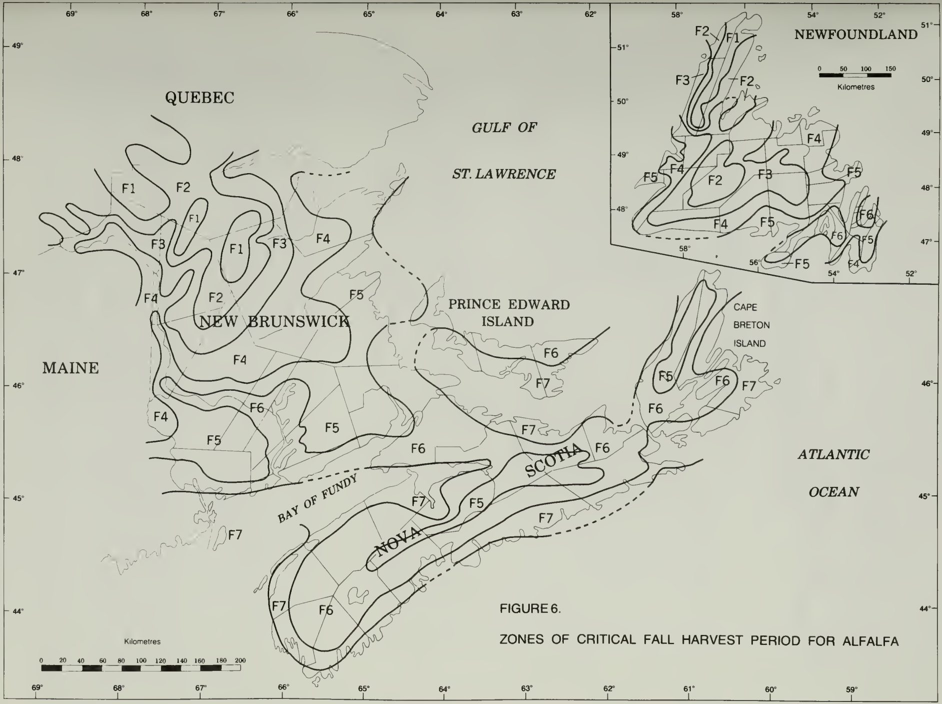

FIGURE 6.

ZONES OF CRITICAL FALL HARVEST PERIOD FOR ALFALFA

The zonation map has been prepared on a relatively broad scale. Variations in the critical harvest period within each zone are likely, depending upon local conditions of shelter and frost. Seasonal weather patterns can also cause some shifts in the critical period from year to year within a particular zone, although such variation is not likely to be large (Fulkerson, 1970).

Table 4. Critical fall harvest period for alfalfa for zones in Figure 6

Zone	Critical Fall Harvest Period	
	Start of period *1	End of period *2
F1	Aug. 5 or earlier	Sept. 20 or earlier
F2	Aug. 6-10	Sept. 21-25
F3	Aug. 11-15	Sept. 26-30
F4	Aug. 16-20	Oct. 1-5
F5	Aug. 21-25	Oct. 6-10
F6	Aug. 26-30	Oct. 11-15
F7	Aug. 31-Sept. 4	Oct. 16-20
F8	Sept. 5 or later	Oct. 21 or later

*1 Based on date when 450 GDD are remaining in the fall.
*2 Based on 45 days after the starting date.

In areas of the region where alfalfa production is feasible, it is best not to harvest alfalfa during the critical period indicated by the zonation map as this prevents the plants from reaching adequate hardiness before entering the dormant stage (Fulkerson, 1970). Harvesting around the middle of the critical period results in the most damage since this will cause plants to enter dormancy with the lowest levels of food reserves (Fulkerson, 1974). Harvesting before the critical period allows the plants to enter later growth stages during which it develops buds on basal stems and crowns and begins to store sufficient food reserves in the roots. These buds must be well protected during winter, as the number of survived buds determines the number of new shoots in the spring. Added protection can be provided to the buds by leaving the fall growth to act as a windbreak and catch the snow over the winter. If winterkill of alfalfa is not a problem, the critical harvest period could possibly be shortened somewhat at either end without causing a significant decline in survival. However, this would have to be determined by experience within a local area.

The zonation map should be helpful in formulating recommendations on harvest management of alfalfa in late summer and fall. Following the suggested cutting practices does not guarantee good survival, but will assist in reducing the risk of winter injury. The zonation map may also be useful for other crop species that are subject to winterkill and that require a fall rest period. For example, experimental data from Ontario have indicated that birdsfoot trefoil also requires a fall rest period, although the critical fall harvest date when most damage is sustained may be more than a week earlier than for alfalfa (Fulkerson, 1982). Other species to which this zonation may apply include clover and less hardy grass species such as orchardgrass and perennial ryegrass.

3.3 Zones for harvest frequency and potential yield

The variation in the index of growing season length (DAYS) in the region is demonstrated by the zonation map in Figure 7. The range in values of this index associated with each zone is shown in Table 5. This index exceeds 75 days in part of the Saint John River Valley, in the Annapolis Valley, and in part of the north shore of Nova Scotia. Most of the remainder of the major agricultural regions in the Maritimes fall in the H2 zone which has between 60 and 74 days. In Newfoundland, the index DAYS ranges from less than zero in the extreme north to over 45 days in the Humber Valley region, the Grand Falls-Gander Lake area, and in the vicinity of St. John's. In Labrador the date when 350 GDD have accumulated in spring generally falls 10 to 30 days after the date when 450 GDD remain in autumn.

Table 5. Growing season length criterion for zones in Figure 7

Zone	Days*	Zone	Days*
H1	75 or more	H4	39-20
H2	74-60	H5	19-0
H3	59-40	H6	less than 0

* In addition to indicated number of days, there are 350 GDD in spring and 450 GDD in fall available for crop growth.

Results from regional variety trials conducted from 1971 to 1981 by the Advisory Committee on Forage Crops (formerly the Forage Sub-Committee of the Atlantic Field Crops Committee) and from field experiments on forage management by Kunelius et al. (1976, 1977b, 1978, 1980) and by MacLeod et al. (1972) were examined to assess potential yields and optimum harvest

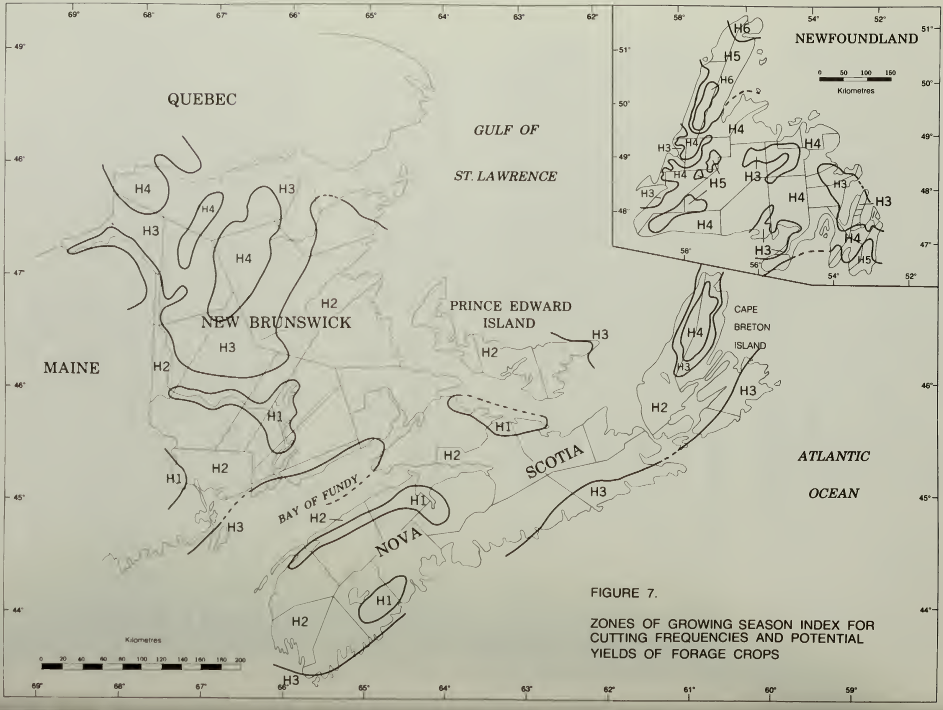

FIGURE 7.

ZONES OF GROWING SEASON INDEX FOR CUTTING FREQUENCIES AND POTENTIAL YIELDS OF FORAGE CROPS frequencies within specific zones in the region. Since field trials were conducted in only three of the six zones, the proposed guidelines are somewhat speculative and need to be verified or adjusted as more information becomes available from field trials or farming experience. Data on red clover were particularly scarce due to difficulties in achieving adequate winter survival within experimental plots in many years. Data on orchardgrass were also relatively few in comparison with most other forage crop species.

Tables 6 and 7 list estimated optimum harvest frequencies and potential yields, respectively, in each zone in Figure 7 for several forage species grown in the region. Potential yields are yields which should be achievable with good management under present technology. Yield estimates are based on yields recorded in field trials conducted at research stations in years with relatively good winter survival. Overwintering damage can seriously reduce yields of alfalfa, clover and orchardgrass in some years, thus making it difficult to achieve potential yields consistently year after year. The proposed cutting frequencies attempt to balance quality and yield. More frequent harvests will often improve forage quality but result in a decline in yield or persistence.

Table 6. Estimated optimum harvesting frequencies of several forage species for each zone in Figure 7

Forage species	Optimum harvesting frequency					
	H1	H2	H3	H4	H5	H6
Annual ryegrass*1	4	4-3	3-2	2	2-1	-
Alfalfa	3	3-2	2	1	1-0	-
Orchardgrass	4-3	4-3	3	2	1	1
Timothy & bromegrass	2	2	2	2	1	1
Red clover*2	2	2	2-1	1	1-0	-

*1 Cutting frequency in seeding year; all others in post-seeding years.

*2 Double cut cultivars such as Ottawa and Lakeland.

As indicated in Table 6, the optimum cutting frequency for annual ryegrass in the most favourable production zones H1 and H2 is four times (Kunelius, 1980; Kunelius and Calder, 1978) but up to five cuts are feasible. Potential yields range from about 8 tonnes dry matter per hectare in the more favourable production areas to less than 5

Table 7. Estimated average potential dry matter yields of several forage species for each zone in Figure 7

Forage species	Average potential dry matter yield (tonnes/ha)*1					
	H1	H2	H3	H4	H5	H6
Annual ryegrass*2	8.0	8.0	7.0	5.0	3.0	-
Alfalfa	8.5	8.5	8.5	6.5	4.0	-
Orchardgrass	7.0	7.5	6.5	5.5	4.0	3.5
Bromegrass	7.5	8.0	7.0	6.0	5.0	4.0
Timothy	8.5	9.0	9.0	8.0	6.0	5.0
Red clover*3	8.0	8.5	7.5	6.0	4.0	-

*1 Yields are based on assumption that cutting frequencies are similar to those listed in Table 6.
*2 Yields in seeding year; all others in post-seeding years.
*3 Double cut cultivars such as Ottawa and Lakeland.

tonnes per hectare in zones with shorter growing seasons. One reason why annual ryegrass is becoming popular in the region is because of its ability to supply quality forage for livestock in late fall when most perennial grasses are unproductive (Kunelius, 1980; Kunelius and Calder, 1978).

The suggested cutting frequencies for alfalfa are based on the assumption that at least 40 days are required for regrowth after the first cut and prior to the fall rest period when harvesting must be avoided. Thus only one cut is feasible in zone H4 while two cuts can be harvested in zone H3. In zones H1 and H2 there is a possibility of two additional harvests before the fall rest period. These guidelines for harvesting frequency are general and need to be modified according to local experience. For example, if persistence or winter survival is poor, the number of cuts may need to be reduced, while an extra harvest may be feasible late in the fall following the critical harvest period if winterkill is not a problem (MacLeod et al., 1972). Fewer harvests may give better results in years when growth is restricted by abnormally cool temperatures or lack of moisture. In the most favourable production areas (zones H1, H2 and H3) average yields of 8.5 tonnes dry matter per hectare are feasible under good management, normal climate, and good winter survival (Table 7). In zones H4 and H5 potential yields are depressed partly because only one harvest can be taken.

Orchardgrass is a fast growing cool season perennial which can be harvested 3 or 4 times per season in the most favourable areas for production in the region (Kunelius and Suzuki, 1977b). However, it is susceptible to winterkill and may require a long fall rest period similar to alfalfa (Kunelius and Suzuki, 1977a). If winter survival is less than adequate, the number of cuts may need to be reduced from those indicated in Table 6. Average yields of 7 tonnes dry matter per hectare or more are achievable in the more favourable production areas (zones H1 and H2) while yields are limited by cool short growing seasons in zones H5 and H6.

Timothy is the main forage species used in the region and is capable of producing 8 tonnes dry matter per hectare or more in zones H1 to H4 with good management. Two cuts are feasible in these zones. More frequent cutting reduces yields but produces higher quality forage (Kunelius et al., 1976). Bromegrass is noted for its strong second growth and superior performance under dry conditions in comparison to timothy, although it is somewhat less hardy. Two cuts are possible except in the zones with the shortest growing season (H5 and H6).

Two cuts of red clover are feasible in zones H1 to H3 if early-flowering cultivars such as Lakeland and Ottawa are grown. In zones H4 and H5 only one cut is feasible due to shorter growing seasons. Field trial data indicate that the second cut usually can be taken after 50 days or more of regrowth. Red clover yields of 8.0 tonnes dry matter per hectare can be achieved in the more favourable climatic zones. However, red clover is a short-lived legume which is frequently winterkilled and therefore is most useful in short-term rotations (Atlantic Field Crops Committee, 1980). It is also more difficult to field cure as hay than most other forage species.

The general guidelines on cutting frequencies and potential yields apply to near average weather conditions. Abnormal weather conditions in any given year can affect the optimum cutting frequency and yield of most species. In most cases the final decision on cutting frequency must be reached by considering a number of factors including quality, yield, stand persistence, winter survival, seasonal weather conditions, and storage method (hay or silage).

The proposed zonation map (Figure 7) will be useful in formulating recommendations on cutting frequencies and potential yields of forage crops in various parts of the region. Further improvements in this zonation scheme are required which take into greater consideration the influence of factors such as winter survival, available moisture and forage quality on optimum harvesting frequencies and potential yields.

3.4 Drying index and water deficit zonation

A zonation map indicating relative drying conditions for making hay in the region is shown in Figure 8. Zone boundaries were determined by arbitrarily selected values of the normalized drying index as indicated in Table 8. This table also shows the range in the drying index itself and

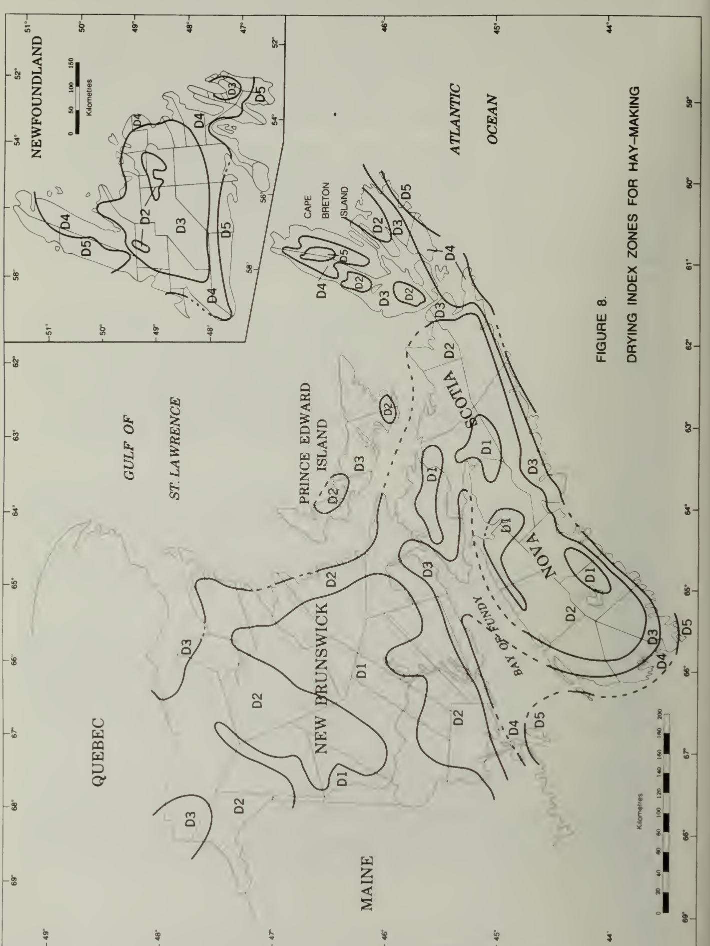

FIGURE 8.

DRYING INDEX ZONES FOR HAY-MAKING

gives a qualitative rating of haymaking conditions for each zone. A more detailed analysis of hay-drying conditions in relation to the climate in each zone is needed for a more quantitative assessment of hay-drying potential. However, the present map provides a good relative indication of drying conditions in the region.

The best drying conditions are found in zone D1 which has a normalized index of 90, and an actual drying index value of 325 mm. This zone is found along a large part of the Saint John River valley and stretches into a large section of eastern New Brunswick. The zone is also present in several regions of Nova Scotia, including part of the Annapolis Valley, an area south of Truro and a portion of the north shore region, which represent the main farming areas of this province. Prince Edward Island is predominantly zone D3, with a normalized index between 65 and 80. Less favourable drying conditions in that province are not from higher rainfall, but because of lower PE due to depressed daytime temperatures and higher humidities. Lower drying potential in much of Newfoundland, most of which falls in zones D3 to D5, is similarly more due to lower PE values than to higher rainfall.

In comparison to PE, average rainfall is relatively uniform throughout the Atlantic region for the period June-August. Most of the region receives an average of 230 and 280 mm of rainfall over the 3-month period, while PE ranges from below 250 mm to over 400 mm.

Table 8. Range in drying indices for zones in Figure 8

Map Zone	Drying Index (mm)	Normalized Index*	Description of haymaking Conditions
D1	325	90	Fair-good (most favourable field drying conditions in the region)
D2	290-325	80-90	Fair
D3	235-290	65-80	Fair-poor
D4	180-235	50-65	Poor
D5	180	50	Very poor (lowest potential for field drying in the region)

*Normalized Index = $\frac{\text{Drying Index}}{\text{Max. Drying Index}}$ x 100, where Max. Drying Index is 360 mm.

The zonation map provides a good indication of the relative drying conditions in the region and should be useful for making recommendations on harvesting and conservation methods when combined with additional information on hay-making conditions in each zone. Further studies to quantify the relationship between climate and hay-drying potential in each zone would be of benefit in this regard. Variation in drying rates for hay-making among crop species needs to be considered in the application of a drying zonation system.

A zonation map for water deficits is shown in Figure 9. Ranges in water deficits and APWL values in each of the 5 zones used are shown in Table 9. The zone boundaries were selected on the basis of 25 mm intervals in water deficits for soils with 100 mm WHC. Water deficits for 50 mm and 200 mm WHC's are also shown in the table.

Table 9 indicates that forage crops grown in areas zoned W4 and W5 can experience significant water deficits if soils have less than 100 mm WHC. However, in zones W1 and W2, even shallow rooted crops like timothy are unlikely to experience significant water stress in an average year.

Table 9. Range in Accumulated Potential Water Loss (APWL) and water deficits for zones in Figure 9

Water Deficit Zone	APWL range (mm)	Approximate water deficit range (mm) Soil water holding capacity (WHC) 50 mm	 100 mm	 200 mm
W1	0	nil	nil	nil
W2	0-78	0-40	0-25	0-15
W3	78-116	40-75	25-50	15-30
W4	116-150	75-105	50-75	30-45
W5	150	105	75	45

According to Figure 9, under similar soil conditions (ie. WHC and drainage) forage crops are most likely to be affected by water stress in part of the lower Saint John River valley and eastern regions of New Brunswick, and in the Annapolis Valley and part of the north shore regions of Nova Scotia. However, these regions are least likely to be affected by problems relating to waterlogging of soils, leaching of nutrients and denitrification during summer months under given soil conditions.

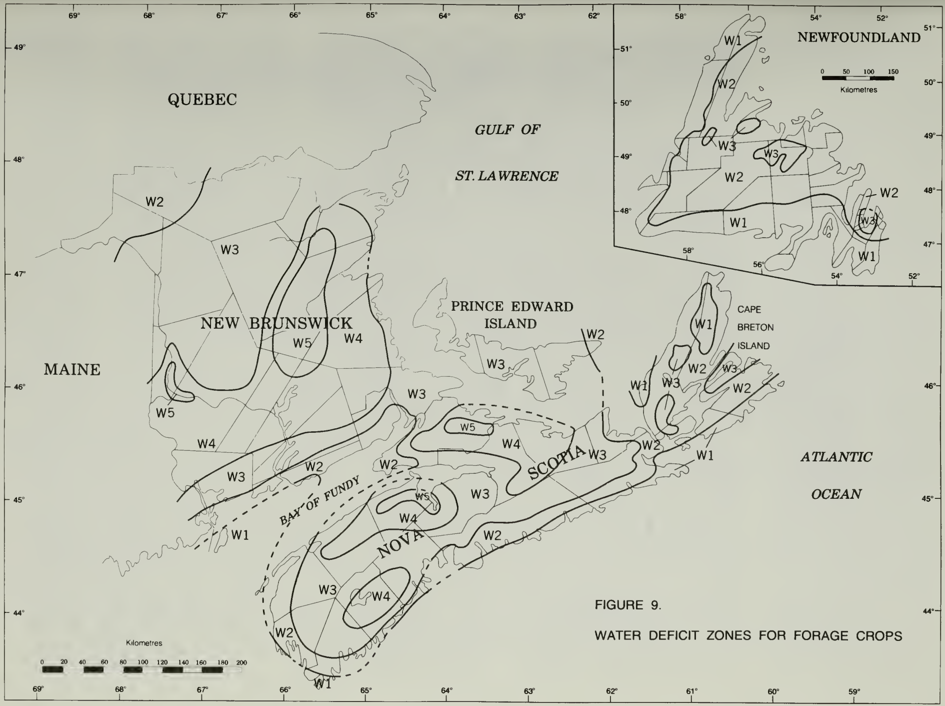

FIGURE 9.

WATER DEFICIT ZONES FOR FORAGE CROPS

Areas zoned W1 or W2 are least likely to experience significant water stress, while the probabilities of moisture surpluses which may cause excessive leaching and denitrification are the greatest. In New Brunswick, zones W1 and W2 are found in the extreme northwest region and along the southern coast bordering the Bay of Fundy. In Nova Scotia, these zones are mainly confined to areas along the southern and western coast and to areas in Cape Breton Island. Most of Newfoundland is in zones W1 and W2, with the exception of a few isolated regions. In zone W1, APWL values are less than zero, indicating that rainfall exceeds PE even during the summer months.

It is useful to compare these estimates of Thornthwaite water deficits with irrigation requirements or water deficits calculated by Coligado et al., (1968) who used a daily water budgeting technique described by Baier and Russelo (1968). Average water deficits in this study for soils with 200 mm WHC were comparable to those by Coligado et al. (1968) at a storage capacity of 100 mm (4 inches), a consumptive use factor (CU) between 1.0 and 0.75 and a risk level of 50 percent. Water deficits for 100 mm WHC were similar to Coligado's at a storage capacity of 50 mm (2 inches) and a CU factor of 0.75. Water deficits for soils with 50 mm WHC were comparable to Coligado's at a storage capacity of 25 mm (1 inch) and CU factor between 0.75 and 0.5. Since storage capacity as used by Coligado et al. (1968) is equivalent to 50 percent of WHC used in this study, the water deficits determined by these two methods are remarkably similar.

Sly and Coligado (1974) developed a simple method for computing seasonal water deficits which was used to prepare agroclimatic maps of Canada. A soil climate classification system was subsequently designed for Canada on the basis of seasonal water deficits (Baier and Mack, 1973; Clayton et al., 1977; Mack, 1970). Water deficit zones in this study are compared with the moisture subclasses used in the soil climate map of Canada in Table 10, thus linking the results to a nationally accepted classification system. This comparison provides a means of linking water deficits determined by the Thornthwaite approach to the Canadian soil climate classification system in the Atlantic region. A qualitative description of the moisture stress likely experienced for timothy and alfalfa in each zone is also presented in Table 10.

Irrigation requirements or water deficits computed by Sly and Coligado (1974) assume that when the readily available water (50 percent of WHC) stored in the soil is depleted, the additional water required is added by irrigation. Since forages are produced under non-irrigated conditions in the Atlantic region, the Thornthwaite procedure was considered more applicable to this study. The present study uses data from more climatic stations in the region and from the most recent 30-year normal period. In spite of differences in methods and analyses period, the present results appear to be relatively compatible with results from previous water deficit zonation studies of the region.

The precise extent to which water deficits limit forage yields in each zone is presently not known. Further research is required to help determine these relationships and thereby assist in rating land for forage

Table 10. Qualitative comparison between water deficit zones, Canada Soil Climate Map moisture classes* and moisture stress on two forage species

	Comparative moisture subclass, Canada Soil Map		Qualitative description of water stress on forage crops**					
			Water holding capacity (WHC) of soil to 60 cm depth					
			200 mm		100 mm		50 mm	
Zone	Symbol	Moisture	timothy	alfalfa	timothy	alfalfa	timothy	alfalfa
W1	c	subaquic	none	none	none	none	none	none
W2	d	perhumid	no sig. (12 mm)	no sig. (8 mm)	no sig. (20 mm)	no sig. (12 mm)	slight (30 mm)	no sig. (20 mm)
W3	e	humid	slight (38 mm)	no sig. -slight (23 mm)	slight -sig. (60 mm)	slight (38 mm)	sig. (75 mm)	slight -sig. (60 mm)
W4	ef	humid-subhumid	slight -sig. (63 mm)	slight (38 mm)	sig. (90 mm)	slight -sig. (63 mm)	sig.-mod. (110 mm)	sig. (90 mm)
W5	f	subhumid	sig. (80 mm)	slight -sig. (50 mm)	sig.-mod. (110 mm)	sig. (80 mm)	mod. (135 mm)	sig.-mod. (110 mm)

* Based on 50% risk level, soil water storage capacity of 50 mm (equivalent to WHC of 100 mm) and Consumptive Use factor of 0.75.

** Description is based on average conditions; more or less severe stress will occur in drier or wetter than normal season; sig. = significant, mod. = moderately severe. Approximate average water deficits in each zone are indicated in brackets, and are based on the assumption that the water holding capacity for timothy is 50% of the value for alfalfa because of a shallower root system.

production potential and in evaluating yield response to irrigation. Variations in characteristics such as water use, drought resistance and resistance to waterlogging among crop species need to be taken into consideration in the application of water deficit zonation systems.

4. CONCLUSION

The results of climatic analyses presented here will be useful for formulating more specific recommendations on production and management of forage crops in the Atlantic region. However, available experience in crop production in each part of the region will also need to be considered. The zonation is on a scale which does not account for variations in crop response within zones resulting from differences in micro-climatic conditions. Variations in climate between years which influence the production and management of forage crops was also not taken into consideration in this study. It should be noted that the transition between zones on the maps is usually gradual and not abrupt as may be implied.

The criteria used and the interpretations applied will require improvement and adjustment as additional information on forage crop production and management becomes available from research trials and field experience and as existing climatic resources within the region are better defined. The results should not be interpreted as a recommendation that the species and cultivars referred to are well adapted to all zones in the region. Rather, the study provided guidelines on applicable management practices if local experience has found production of specific cultivars to be feasible.

Simple procedures for calculating climatic criteria used in zonation are described which make use of monthly climatic normals. These facilitate the use of data from stations with relatively short term normals which have been adjusted to the latest 30-year normal period. The procedures also simplify calculations for other normal periods as may be required. Several areas requiring additional research have been identified. The zonation maps should be helpful in selecting suitable locations for conducting field experiments. Finally, the results of this study have significance for land evaluation, particularly when integrated with information on soils in the region.

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6. APPENDIX

Climatic data from 232 stations in the Atlantic region listed in Table 11 were used in the forage crop zonation study. A map is supplied in this appendix which shows the approximate location of each climate station (Fig. 10). Parameters that were derived from station data are listed in Table 11. Following is a brief explanation of each parameter listed:

Column
No.

1. Station number. This number was assigned on the basis of an alphabetical listing of stations by province. It corresponds with numbers in Fig. 10.

2. Station name. Station names were taken from published normals for the 1951-1980 period by Environment Canada (1982). Where the same name is assigned to more than one station, the station elevation is given in brackets following the name.

3. Type of normal. The code for length of record is based on temperature and precipitation normals published for the 1951-1980 period by Environment Canada (1982). Where the normal period for these two variables differ, the temperature code is given first, followed by the code for precipitation, e.g. 1/2. The codes refer to the following periods of record:

Code	
1	complete 30 years
2	25 to 29 years
3	20 to 24 years
8	adjusted normals based on 5 to 19 years inclusive from 1951 to 1980, and any other available data from 1931 to 1950

First order synoptic stations with hourly observations are identified with an asterisk (*) following the type of normal. These stations may have a bias in any data derived from temperature due to a shift in the climatological day for minimum temperature from ordinary climate stations.

4. 450 GDD date in spring. This is the average date when 450 growing degree-days above 5°C have accumulated in spring based on regression equation (2) using May/June mean air temperature for the 1951-1980 normal period. The 350 GDD date is generally about 10 days earlier.

5. 450 GDD date in fall. This is the average date when 450 growing degree-days above 5°C are remaining in fall, as estimated using regression equations (4) and (6) and September/October mean air temperature for the 1951-1980 normal period.

6. Days. This represents the index of growing season length as determined by the time interval in days between the date when 350 GDD have accumulated in spring and when 450 GDD are remaining in the fall.

7. Drying index. The value of the drying index, in mm, is determined using equation (7).

8. Normalized drying index. The values in this column are calculated using equation (12). Since it is a "normalized" index, it has no units. In a few cases the index value may exceed 100.

9. PE. The potential evaporation in mm from June through August is estimated by the Baier and Robertson method (equations (8) and (11)).

10. Precip. The average total precipitation (P) from June through August, in mm, for the 1951-1980 normal period.

11. APWL. The accumulated potential water loss in mm is determined for the period June through August using the formula APWL = PE - P.

12. Water deficit. The average water deficits (mm) for soils with 50, 100 and 200 mm water holding capacity are calculated from APWL values using equations shown in Table 2. Water holding capacity is here defined as the amount of soil water between field capacity and the permanent wilting point.

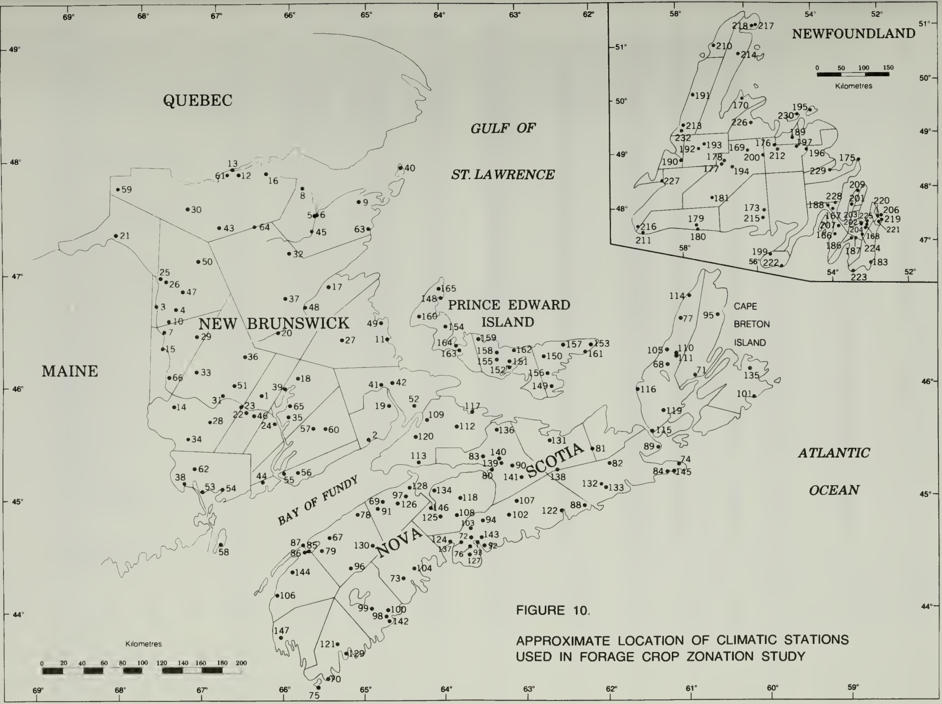

FIGURE 10.

APPROXIMATE LOCATION OF CLIMATIC STATIONS USED IN FORAGE CROP ZONATION STUDY

Table 11. List of climatic stations used in zonation study and derived data

1	2	3	4		5		6	7	8	9	10	11	12		
Station #	Station Name	Type of Normal	450 GDD date in spring		450 GDD date in fall		Growing season index	Drying index	Normalized drying index	PE (mm)	Precip. (mm)	APWL (mm)	Water deficit (mm)		
			Mo.	Day	Mo.	Day	DAYS	(mm)					Soil water holding capacity 50 mm	100 mm	200 mm
	NEW BRUNSWICK														
1	Acadia Forest Exp. St.	3	6	27	8	20	63	360	100	415	275	141	96	68	41
2	Alma	2	7	5	8	26	61	257	71	319	310	9	2	1	0
3	Aroostook	1	6	25	8	19	64	328	91	387	294	93	53	34	20
4	Arthurette Birch Ridge	8	6	27	8	16	59	318	88	375	245	90	51	32	19
5	Bathurst (12m)	3	6	30	8	21	62	320	89	368	245	124	81	55	33
6	Bathurst (5m)	8	6	27	8	24	67	310	86	358	241	117	74	50	30
7	Beechwood	8	6	25	8	20	66	344	96	402	289	113	71	47	28
8	Belledune	8	7	3	8	20	58	288	80	334	229	105	63	41	24
9	Bertrand	8	7	3	8	18	56	311	86	360	247	113	71	47	28
10	Bon Accord	8	7	3	8	10	47	246	68	325	396	-70	0	0	0
11	Buctouche	8	6	28	8	28	71	301	83	348	240	109	67	44	26
12	Campbellton	8*	6	28	8	18	60	313	87	367	270	98	57	37	22
13	Campbellton Power St.	8	6	28	8	16	58	312	87	369	288	81	43	27	16
14	Canterbury	8	6	26	8	19	63	342	95	396	270	126	83	56	34
15	Centreville	8	6	26	8	18	62	331	92	390	295	95	55	35	21
16	Charlo A	8*	7	5	8	13	49	291	81	347	279	68	32	20	11
17	Chatham A	1*	6	27	8	22	65	337	94	389	257	132	88	61	37
18	Chipman	8	6	25	8	23	68	377	105	431	273	158	113	82	52
19	Dawson Settlement	8	6	27	8	25	68	293	81	347	272	75	39	24	14
20	Doaktown	2	6	29	8	20	62	357	99	405	244	161	116	85	53
21	Edmunston Fraser Co.	2	6	26	8	17	62	316	88	378	307	71	35	21	12
22	Fredericton A	1*	6	23	8	24	71	353	98	405	261	145	100	71	43
23	Fredericton CDA	1	6	24	8	25	72	344	96	397	265	132	88	61	37
24	Gagetown 2	1	6	22	8	29	78	332	92	382	252	130	86	59	36
25	Grand Falls	8	6	26	8	17	62	315	87	370	280	91	51	32	19
26	Grand Falls Drummond	8	6	28	8	14	57	294	82	358	316	42	14	9	5
27	Harcourt	8	7	1	8	17	57	352	98	405	266	139	95	66	41
28	Harvey Station	2	6	26	8	23	68	310	86	365	274	91	52	33	19
29	Juniper	8	7	3	8	10	47	355	99	416	303	113	71	47	28
30	Kedgwick	8	7	6	8	6	40	316	88	379	315	64	29	18	10
31	Keswick Ridge Mactaquac	8	6	20	8	31	81	334	93	387	262	124	81	55	33
32	Little River Mine	8	7	3	8	13	50	299	83	353	270	83	45	28	16
33	Mapleton	8	6	28	8	18	60	315	88	373	290	84	45	28	16
34	McAdam	2	6	26	8	22	67	343	95	398	275	122	79	53	32
35	McDonalds Corner CDA	8	6	25	8	27	72	322	90	371	245	126	83	56	34
36	McGivney	3	6	28	8	19	61	327	91	382	277	105	64	41	25
37	McGraw Brook	8	6	28	8	19	62	364	101	411	235	176	131	97	62
38	Milltown	8	6	23	8	29	77	345	96	392	235	157	112	81	51
39	Minto	2	6	23	8	29	77	330	92	383	263	120	77	52	31
40	Miscou Island (Aut)	8*	7	9	8	21	52	261	73	307	226	81	43	27	15
41	Moncton	1	6	27	8	25	68	339	94	391	262	129	86	59	36
42	Moncton A	1*	6	29	8	24	65	321	89	374	263	111	69	45	27

Table 11 (cont'd). List of climatic stations used in zonation study and derived data

1 Station #	2 Station Name	3 Type of Normal	4 450 GDD date in spring Mo. Day	5 450 GDD date in fall Mo. Day	6 Growing season index DAYS	7 Drying index (mm)	8 Normalized drying index	9 PE (mm)	10 Precip. (mm)	11 APWL (mm)	12 Water deficit (mm) Soil water holding capacity 50 mm	 100 mm	 200 mm
43	Mount Carleton	8	7 5	8 10	45	337	94	392	272	120	77	51	31
44	Musquash	2	7 3	8 22	59	308	86	363	276	87	48	30	18
45	Nepisiguit Falls	2	6 31	8 18	58	351	98	400	242	158	113	82	51
46	Oromocto	3	6 23	8 25	71	340	95	393	263	130	87	60	36
47	Plaster Rock NBEPC	8	6 26	8 18	62	333	92	394	308	87	48	30	18
48	Renous	3	6 27	8 19	62	358	99	409	255	154	109	79	49
49	Rexton	1	6 29	8 24	65	327	91	377	249	128	84	58	35
50	Riley Brook	8	6 30	8 13	54	346	96	409	315	94	54	34	20
51	Royal Road	8	6 27	8 18	62	335	93	393	290	103	62	40	24
52	Sackville	2	6 30	8 28	68	291	81	343	263	81	43	27	15
53	St. Andrews	2	6 28	8 30	72	289	80	339	251	88	49	31	18
54	St. George	1	7 1	8 25	65	323	90	372	243	129	85	58	35
55	Saint John	8	7 2	8 29	68	238	66	294	279	15	3	2	1
56	Saint John A	2*	7 3	8 23	60	272	76	332	300	33	10	6	3
57	Searsville	8	6 27	8 24	67	310	86	364	271	93	53	34	20
58	Southwest Head	8	7 12	8 30	59	175	49	226	254	-28	0	0	0
59	Summit Depot	8	7 10	8 5	35	275	77	342	332	10	2	1	0
60	Sussex	1/2	6 27	8 24	68	349	97	396	237	159	114	83	52
61	Tide Head	8	6 30	8 16	57	323	90	380	288	92	53	33	20
62	Tower Hill CDA	8	6 25	8 26	71	315	87	371	281	90	50	32	19
63	Tracadie	8	7 3	8 24	62	281	78	323	207	116	73	49	29
64	Upsalquitch Lake	8	7 11	8 3	33	232	64	283	254	29	8	5	2
65	Wiggins Point	8	6 23	9 3	81	315	87	370	276	94	54	35	20
66	Woodstock	3/8	6 22	8 24	72	353	98	402	246	156	111	81	50
	<u>NOVA SCOTIA</u>												
67	Annapolis Royal	2	6 28	8 31	73	311	86	364	266	98	58	37	22
68	April Brook IHD	2	7 6	8 25	59	300	83	357	286	71	35	22	12
69	Aylesford CDA EPF	8	6 27	8 26	70	336	93	385	247	139	94	66	40
70	Baccaro	3/8	7 15	9 1	57	186	52	235	246	-12	0	0	0
71	Baddeck	2/1	7 4	9 1	68	269	75	326	287	39	13	8	4
72	Bedford	8	6 30	8 28	69	299	83	356	285	70	34	21	12
73	Bridgewater	8	6 26	8 29	74	349	97	403	270	133	89	62	37
74	Canso	8	7 19	9 1	54	195	54	262	335	-73	0	0	0
75	Cape Sable	2	7 24	8 29	46	113	31	160	239	-77	0	0	0
76	Chain Lake	8/2	7 1	8 31	70	301	84	361	297	64	29	18	10
77	Cheticamp	8/3	7 6	8 29	63	248	69	303	272	31	9	5	3
78	Clarence	3	6 26	8 28	72	322	90	375	261	114	71	47	28
79	Clementsvale	8	6 29	8 24	65	321	89	371	251	121	77	52	31
80	Clifton	8/2	7 1	8 25	64	295	82	345	248	97	56	36	21
81	Collegeville	1/2	7 3	8 26	63	314	87	368	271	97	57	36	21
82	Copper Lake	8*	7 4	8 26	62	305	85	360	279	81	44	27	16
83	Debert A	8*	6 29	8 26	67	309	86	372	315	57	24	15	8
84	Deming	3	7 25	9 3	50	153	42	216	315	-99	0	0	0

Table 11 (cont'd). List of climatic stations used in zonation study and derived data

1	2	3	4		5		6	7	8	9	10	11	12		
Station #	Station Name	Type of Normal	450 GDD date in spring Mo.	Day	450 GDD date in fall Mo.	Day	Growing season index DAYS	Drying index (mm)	Normalized drying index	PE (mm)	Precip. (mm)	APWL (mm)	Water deficit (mm) Soil water holding capacity 50 mm	100 mm	200 mm
85	Digby	8	6	28	9	1	74	278	77	337	298	40	13	8	4
86	Digby CKDY	8	6	28	9	2	76	274	76	322	237	85	46	29	17
87	Digby Prim Point	8	7	1	9	3	73	243	67	296	266	30	8	5	3
88	Ecum Secum	1*	7	18	8	29	52	186	52	252	330	-78	0	0	0
89	Eddy Point	8*	7	10	9	1	62	237	66	295	292	3	1	0	0
90	Fraser Brook IHD	8	7	5	8	22	57	321	89	376	276	100	59	38	23
91	Greenwood A	1*	6	24	8	29	75	351	97	398	239	159	114	83	52
92	Halifax	3*	6	29	9	10	81	261	73	316	275	41	14	8	5
93	Halifax Citadel	8	6	29	9	5	77	261	72	317	284	33	10	6	3
94	Halifax Int'l A	3*	6	30	8	29	69	289	80	348	295	53	21	13	7
95	Ingonish Beach	1	7	8	8	31	63	274	76	334	299	35	11	7	4
96	Kejimkujik Park	8	6	26	8	28	72	321	89	377	280	97	56	36	21
97	Kentville CDA	1	6	24	9	1	78	330	92	378	240	138	94	65	40
98	Liverpool	8*	6	30	9	2	73	277	77	330	265	65	30	19	11
99	Liverpool Big Falls	2	6	24	9	2	79	350	97	399	248	152	107	77	47
100	Liverpool Milton	8	6	25	9	4	80	330	92	379	245	134	90	62	38
101	Louisbourg	8	7	23	9	1	50	177	49	241	324	-82	0	0	0
102	Lower Meaghers Grant	8	7	2	8	31	70	322	90	375	261	114	71	47	28
103	Lower Sackville	8	6	30	9	1	72	304	84	360	282	79	41	26	15
104	Mahone Bay	8	6	28	8	27	69	321	89	377	280	97	57	36	21
105	Margaree Forks	8	7	6	8	27	61	292	81	346	272	75	38	24	13
106	Meteghan River	1/3	7	3	8	31	68	230	64	275	225	50	19	12	7
107	Middle Musquodoboit	8	7	2	8	28	67	340	95	397	284	113	71	47	28
108	Mount Uniacke	8	7	2	8	25	63	309	86	366	287	79	41	26	15
109	Nappan CDA	1	6	30	8	27	67	311	86	361	254	108	66	43	26
110	Northeast Margaree (84m)	8	7	7	8	22	56	330	92	380	252	128	84	58	35
111	Northeast Margaree (31m)	8	7	4	8	23	59	325	90	375	250	125	81	55	33
112	Oxford	3/2	6	26	8	26	71	351	98	399	240	159	114	83	52
113	Parrsboro	1/2	7	3	8	26	64	298	83	352	274	78	41	25	15
114	Pleasant Bay Grand Anse	3	7	7	8	27	60	272	76	324	260	65	30	18	10
115	Port Hastings	3/8	7	6	9	3	68	263	73	318	272	46	17	10	6
116	Port Hood	8	7	11	8	30	59	219	61	297	388	-91	0	0	0
117	Pugwash	8	6	25	8	31	76	303	84	344	204	140	96	67	41
118	Rawdon	8	6	30	8	28	68	305	85	357	260	97	57	36	21
119	River Denys	8	7	4	8	25	61	328	91	390	310	81	43	27	15
120	River Hebert	8	6	29	8	24	65	333	93	386	264	122	79	53	32
121	Roseway	2	6	28	8	28	69	313	87	366	267	99	59	38	22
122	Ruth Falls	8	7	7	8	30	64	255	71	325	353	-28	0	0	0
123	Sable Island	1*	7	19	9	13	65	150	42	210	302	-92	0	0	0
124	St. Margaret's Bay	1/2	7	4	8	27	64	294	82	348	274	74	38	23	13
125	Salmon Hole	1/2	6	26	9	2	78	344	96	394	253	141	97	68	42
126	Sharpe Brook IHD	8	6	25	8	31	76	314	87	365	256	109	67	44	26

Table 11 (cont'd). List of climatic stations used in zonation study and derived data

1 Station #	2 Station Name	3 Type of Normal	4 450 GDD date in spring Mo.	Day	5 450 GDD date in fall Mo.	Day	6 Growing season index DAYS	7 Drying index (mm)	8 Normalized drying index	9 PE (mm)	10 Precip. (mm)	11 APWL (mm)	12 Water deficit (mm) Soil water holding capacity 50 mm	 100 mm	 200 mm
127	Shearwater A	1*	7	3	9	3	71	249	69	305	279	26	7	4	2
128	Sheffield Mills	8	6	24	9	1	78	337	94	385	239	145	100	71	44
129	Shelburne	8	6	29	9	4	76	295	82	345	253	93	53	34	20
130	Springfield	1/2	6	27	8	28	71	310	86	367	285	82	44	27	16
131	Stellarton Lourdes	2/3	6	29	8	31	72	322	89	369	236	136	89	62	38
132	Stillwater	8	7	6	8	25	60	327	91	381	271	110	68	45	27
133	Stillwater Sherbrooke	8	7	4	8	29	65	311	86	372	302	70	34	21	12
134	Summerville	8	6	28	8	31	74	320	89	365	223	142	97	69	42
135	Sydney A	1*	7	10	8	28	58	287	80	340	265	75	39	24	14
136	Tatamagouche	8	6	28	9	1	75	327	91	373	230	143	99	70	43
137	Timberlea	8	7	1	8	29	68	313	87	368	275	94	54	34	20
138	Trafalgar	8	7	5	8	21	56	318	88	376	289	86	47	30	17
139	Truro	8*	7	3	8	23	61	324	90	373	248	126	82	56	34
140	Truro NSAC	8	6	29	8	29	70	326	91	375	242	133	89	62	37
141	Upper Stewiacke	1/2	6	31	8	27	67	337	94	390	265	126	82	56	34
142	Western Head AUT	8*	7	14	8	31	58	192	53	244	260	-16	0	0	0
143	Westphal	3/8	7	2	9	1	71	264	73	322	290	32	10	6	3
144	Weymouth Falls	8	6	26	9	2	77	278	77	335	284	51	20	12	7
145	Whitehead	8	7	24	8	31	47	198	55	249	258	-9	0	0	0
146	Windsor Falmouth	8	6	25	8	31	76	332	92	378	229	149	104	74	46
147	Yarmouth A	1*	7	4	8	31	68	232	65	284	256	27	7	4	2
	<u>PRINCE EDWARD ISLAND</u>														
148	Alberton	8	7	4	8	27	63	281	78	325	219	106	65	42	25
149	Alliston	1/2	7	7	8	30	68	299	83	348	244	104	62	40	24
150	Bangor	8	7	3	8	27	64	274	76	321	235	86	47	30	17
151	Charlottetown A	1*	7	3	8	27	64	272	76	323	252	70	35	21	12
152	Charlottetown CDA	1	6	30	8	30	71	273	76	321	243	78	41	25	15
153	East Baltic	8	7	8	8	29	61	248	69	293	226	67	31	19	11
154	Ellerslie	8	6	29	8	29	70	292	81	340	240	100	59	38	23
155	Hunter River	8	7	1	8	29	68	268	74	315	237	78	40	25	14
156	Montague	8	7	3	8	30	68	284	79	327	216	111	69	45	27
157	Monticello Armadale	3	7	7	8	27	61	273	76	320	232	88	49	31	18
158	New Glasgow	8	7	2	8	28	67	282	78	326	224	103	61	40	24
159	New London	8/3	7	3	8	27	65	290	81	336	228	107	66	43	26
160	O'Leary	3	7	2	8	24	63	284	79	330	233	97	57	36	21
161	Souris	8	7	9	8	29	60	251	70	294	216	78	41	25	15
162	Stanhope	8	7	3	8	31	69	257	72	301	219	82	44	28	16
163	Summerside CDA	8	7	2	8	29	68	268	74	315	239	77	40	24	14
164	Summerside A	1*	6	30	8	30	70	273	76	320	232	88	49	31	18
165	Tignish	8	7	2	8	28	67	284	79	328	221	107	66	43	26

Table 11 (cont'd). List of climatic stations used in zonation study and derived data

1	2	3	4		5		6	7	8	9	10	11	12		
Station #	Station Name	Type of Normal	450 GDD date in spring Mo.	Day	450 GDD date in fall Mo.	Day	Growing season index DAYS	Drying index (mm)	Normalized drying index	PE (mm)	Precip. (mm)	APWL (mm)	Water deficit (mm) Soil water holding capacity 50 mm	100 mm	200 mm
	NEWFOUNDLAND AND LABRADOR														
166	Argentia A	8*	7	28	8	25	37	137	38	186	244	-58	0	0	0
167	Arnolds Cove	8	7	28	8	25	37	149	41	200	259	-58	0	0	0
168	Avondale CDA	8	-	-	8	19	-	238	66	291	267	24	6	4	2
169	Badger	8	7	14	8	13	40	282	78	337	274	63	28	18	10
170	Baie Verte	8	7	27	8	9	23	257	71	306	244	62	27	17	10
171	Battle Harbour+	8	8	29	7	31	-18	136	38	183	236	-52	0	0	0
172	Battle Harbour Lor+	3*	8	30	7	28	-21	129	36	174	229	-54	0	0	0
173	Bay D'Espoir Gen. Stn.	8*	7	12	8	20	47	146	68	312	330	-19	0	0	0
174	Belle Isle+	8*	9	10	7	20	-40	80	22	131	256	-125	0	0	0
175	Bonavista	3	8	2	8	19	26	206	57	247	208	39	13	8	4
176	Botwood	8	7	14	8	17	43	277	77	322	222	100	59	38	22
177	Buchans	8	7	28	8	12	34	247	69	303	283	21	5	3	1
178	Buchans A	8*	7	25	8	7	22	264	73	313	244	69	33	20	12
179	Burgeo	8*	7	28	8	18	30	115	32	199	419	-221	0	0	0
180	Burgeo 2	8	8	1	8	17	26	123	34	199	379	-180	0	0	0
181	Burnt Pond	8	7	21	8	9	28	249	69	305	278	27	7	4	2
182	Cape Harrison+	8*	8	28	7	24	-24	151	42	208	282	-74	0	0	0
183	Cape Race (Aut)	8*	8	12	8	16	-7	135	37	196	306	-110	0	0	0
184	Cartwright+	1*	8	15	7	27	-8	212	59	261	243	17	4	2	1
185	Churchill Falls A+	8*	8	8	7	12	-17	193	53	255	312	-57	0	0	0
186	Colinet	1/2	7	25	8	19	35	182	51	247	323	-76	0	0	0
187	Colinet Peat Bog CDA	8	7	25	8	19	35	198	55	262	322	-60	0	0	0
188	Come by Chance	8	7	25	8	22	38	183	51	234	259	-25	0	0	0
189	Comfort Cove	8*	7	19	8	14	35	257	71	310	266	45	16	10	5
190	Corner Brook	1	7	12	8	19	48	244	67	293	242	50	19	12	7
191	Daniels Harbour	1/2*	7	31	8	12	22	152	42	210	290	-81	0	0	0
192	Deer Lake	2	7	16	8	15	40	273	76	325	260	65	30	19	10
193	Deer Lake A	8*	7	18	8	9	32	309	86	359	251	108	66	43	26
194	Exploits Dam	3	7	23	8	9	28	282	78	335	268	68	32	20	11
195	Fogo	8*	7	23	8	16	34	241	67	277	179	98	58	37	22
196	Gander Int'l A	1	7	18	8	14	36	261	73	310	247	64	29	18	10
197	Glenwood	2	7	16	8	15	39	294	82	343	248	96	55	35	21
198	Goose A+	1*	7	24	7	28	13	240	67	301	301	-1	0	0	0
199	Grand Bank	8*	7	23	8	23	40	199	55	247	241	6	1	0	0
200	Grand Falls	3	7	11	8	17	46	290	81	340	248	92	52	33	19
201	Hearts Content	8	7	19	8	23	44	222	62	276	270	7	1	0	0
202	Holyrood	8	7	28	8	16	29	286	79	324	191	133	89	62	38
203	Holyrood Gen. Stn.	8	7	17	8	27	51	254	71	298	216	81	43	27	16
204	Holyrood Ultramar	8	7	16	8	27	52	263	73	306	217	87	50	31	18

Table 11 (cont'd). List of climatic stations used in zonation study and derived data

1	2	3	4		5		6	7	8	9	10	11	12		
Station #	Station Name	Type of Normal	450 GDD date in spring		450 GDD date in fall		Growing season index DAYS	Drying index (mm)	Normalized drying index	PE (mm)	Precip. (mm)	APWL (mm)	Water deficit (mm) Soil water holding capacity		
			Mo.	Day	Mo.	Day							50 mm	100 mm	200 mm
205	Hopedale+	1*	9	2	7	10	-32	131	36	177	229	-52	0	0	0
206	Logy Bay	8	7	23	8	23	40	239	66	281	206	74	38	23	13
207	Long Harbour	8	7	24	8	26	43	185	51	240	277	-37	0	0	0
208	Nain+	8	7	27	7	11	-5	179	50	220	204	16	4	2	1
209	New Chelsea	8	7	21	8	23	42	221	61	271	250	21	5	3	1
210	Plum Point	8	8	1	8	9	17	150	42	204	272	-68	0	0	0
211	Port Aux Basques	2*	8	4	8	17	23	122	34	187	326	-139	0	0	0
212	Rattling Brk Norris Arm	3	7	11	8	18	48	290	81	341	256	86	47	29	17
213	Rocky Harbour	8	7	19	8	15	36	202	56	258	283	-24	0	0	0
214	Roddickton	8	7	31	8	7	17	234	65	282	238	44	16	10	5
215	St. Albans	8*	7	16	8	20	44	216	60	291	375	-84	0	0	0
216	St. Andrews	8*	7	24	8	17	34	220	61	270	253	17	4	2	1
217	St. Anthony (17m)	8*	8	17	8	3	-3	185	51	236	259	-22	0	0	0
218	St. Anthony (105m)	8*	8	17	7	28	-9	157	43	218	306	-89	0	0	0
219	St. John's	8	7	18	8	21	43	246	68	293	237	57	24	15	8
220	St. John's A	1*	7	24	8	17	34	221	62	278	283	-5	0	0	0
221	St. John's West CDA	1	7	22	8	18	36	229	64	283	268	15	3	2	1
222	St. Lawrence	8*	8	7	8	19	22	117	32	183	330	-147	0	0	0
223	St. Shotts	8	8	9	8	20	21	116	32	181	323	-142	0	0	0
224	Salmonier	8	7	23	8	21	38	223	62	283	300	-17	0	0	0
225	Seal Cove	8	7	15	8	24	50	263	73	311	239	72	36	22	13
226	Springdale	2/3	7	18	8	13	36	287	80	335	241	94	54	34	20
227	Stephenville A	1*	7	16	8	19	43	202	56	259	287	-27	0	0	0
228	Sunnyside	8	7	25	8	20	35	199	55	255	280	-25	0	0	0
229	Terra Nova Nat. Park HQ	8	7	16	8	19	43	250	70	301	252	49	18	11	6
230	Twillingate	8*	7	28	8	17	29	207	58	250	215	35	11	7	4
231	Wabush Lake A+	8*	8	8	7	9	-20	206	57	263	284	-21	0	0	0
232	Woody Point	8	7	16	8	18	43	213	59	282	344	-62	0	0	0

+ Indicates stations situated in Labrador.

* Indicates hourly synoptic climate station.

CONVERSION FACTORS

Metric units	Approximate conversion factors	Results in:
LINEAR		
millimetre (mm)	× 0.04	inch
centimetre (cm)	× 0.39	inch
metre (m)	× 3.28	feet
kilometre (km)	× 0.62	mile
AREA		
square centimetre (cm^2)	× 0.15	square inch
square metre (m^2)	× 1.2	square yards
square kilometre (km^2)	× 0.39	square mile
hectare (ha)	× 2.5	acres
VOLUME		
cubic centimetre (cm^3)	× 0.06	cubic inch
cubic metre (m^3)	× 35.31	cubic feet
cubic metre (m^3)	× 1.31	cubic yards
CAPACITY		
litre (L)	× 0.035	cubic foot
hectolitre (hL)	× 22	gallons
hectolitre (hL)	× 2.5	bushels
WEIGHT		
gram (g)	× 0.04	oz avdp
kilogram (kg)	× 2.2	lb avdp
tonne (t)	× 1.1	short tons
AGRICULTURAL		
litres per hectare (L/ha)	× 0.089	gallons per acre
litres per hectare (L/ha)	× 0.357	quarts per acre
litres per hectare (L/ha)	× 0.71	pints per acre
millilitres per hectare (mL/ha)	× 0.014	fl. oz per acre
tonnes per hectare (t/ha)	× 0.45	tons per acre
kilograms per hectare (kg/ha)	× 0.89	lb per acre
grams per hectare (g/ha)	× 0.014	oz avdp per acre
plants per hectare (plants/ha)	× 0.405	plants per acre