Snowmelt adjusted USLE erosivity estimates for the Maritime Provinces of Canada

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Gordon, R. and Madramootoo, C. A. 1989. **Snowmelt adjusted USLE erosivity estimates for the Maritime Provinces of Canada.** Can. Agric. Eng. **31**:95–99. Rainfall and runoff erosivity indices for the Canadian Maritime Provinces of Nova Scotia, New Brunswick and Prince Edward Island were calculated based on the once-in-2-yr, 6–h rainfall. Isoerodent maps were plotted based on the calculated rainfall and runoff erosivity indices. Another set of maps with corrections for winter conditions were also plotted. A finer resolution of *R* values is now available for the Maritime Provinces that will improve the quality of soil erosion and conservation designs based on the USLE.

INTRODUCTION

Since the early part of the 20th century, an awareness of the detrimental effects of soil erosion from agricultural land has existed in the Maritime Provinces of Canada. However, soil loss has rarely been measured, particularily in winter.

The universal soil loss equation (USLE) was developed by Wischmeier and Smith (1965) as a tool for the determination of soil erosion resulting from rainfall under various cropping, soil, topographic and climatic conditions. The USLE is given as:

$$A = RKLSCP \quad (1)$$

where:
- A = predicted soil loss (Mg ha^{-1} yr^{-1}),
- R = rainfall and runoff erosivity index (MJ mm ha^{-1} h^{-1} yr^{-1}),
- K = soil erodibility factor (Mg h MJ^{-1} mm^{-1}),
- L = slope length factor,
- S = slope gradient factor,
- C = crop management factor, and
- P = erosion control practice factor.

The rainfall runoff-erosion index (*R*) is one of the primary parameters of the USLE. However, there has been very little published data on *R* values for the agricultural areas of Nova Scotia, New Brunswick and Prince Edward Island. This has led to poor estimates of soil losses due to erosion which, in turn, have restricted conservation management decisions for the maritimes. It has also been difficult to ascertain the seriousness of the erosion problem and to quantify soil loss. Wischmeier and Smith (1978) reported on the two most common methods of estimating the *R* factor. In areas where over 22 yr of rainfall intensity data are available, *R* can be calculated from the following equation:

$$R = EI_{30} \quad (2)$$

where:
- E = rainstorm kinetic energy (MJ ha^{-1}) and
- I_{30} = maximum storm intensity occurring in 30 min (mm h^{-1}).

The above equation has often been inconvenient because of the need for at least 22 yr of data. Furthermore, processing of these data is rather slow and tedious. A more efficient and less time-consuming method is that developed by Ateshian (1974). Madramootoo (1988) applied this method successfully to the Eastern Canadian Provinces of Quebec and Ontario. Based on the once-in-2-yr, 6-h rainfalls, *R* is calculated as follows:

$$R = 0.417P_{2,6}^{2.17} \quad (3)$$

where:
- $P_{2,6}$ = once-in-2-yr, 6-hr duration rainfall (mm).

Foster et al. (1981) used Eq. 3 to plot isoerodent maps for the United States, Hawaii, Puerto Rico and the U.S. Virgin Islands. Recently, Wingham and Stolte (1986) and Madramootoo (1988) published detailed isoerodent maps for the prairie provinces and for Quebec and Ontario, respectively. Wall et al. (1983) determinedd *R* values for Canada east of the Rocky Mountains on a national scale while at the same time stating the need for more definite estimates of *R* within provincial boundaries.

Air masses from as distant as the Arctic and the Gulf of Mexico may end up over the Atlantic region of Canada. As a result, storms are more frequent in this region throughout the year than in any other part of Canada. For this reason, it is not surprising that the largest *R* values in Canada are found in the Maritimes (Wall et al. 1983). This leads, therefore, to a greater risk of soil erosion.

METHODOLOGY

The 6-h duration maps for the mean and standard deviation of the annual extremes of rainfall for Nova Scotia, New Brunswick and Prince Edward Island were selected from the Rainfall Frequency Atlas of Canada (RFAC). A 20–km-square grid system was drawn on 1:500 000 scale provincial maps. This grid resolution was chosen because of a similar resolution for the isohyetal lines on the RFAC.

The once-in-2-yr, 6-h rainfalls were calculated at each of the grid points from the following formula (Hogg and Carr 1985):

$$X_2 = \overline{X} + K_2S \quad (4)$$

where:
- X_2 = once-in-2-yr, 6-h extreme rainfall (mm),
- $\overline{X}$ = mean annual, 6-h extreme rainfall (mm),
- K_2 = return period frequency factor (−0.164 for a 2-yr return period), and
- S = standard deviation of the mean annual, 6-h extreme rainfall (mm).

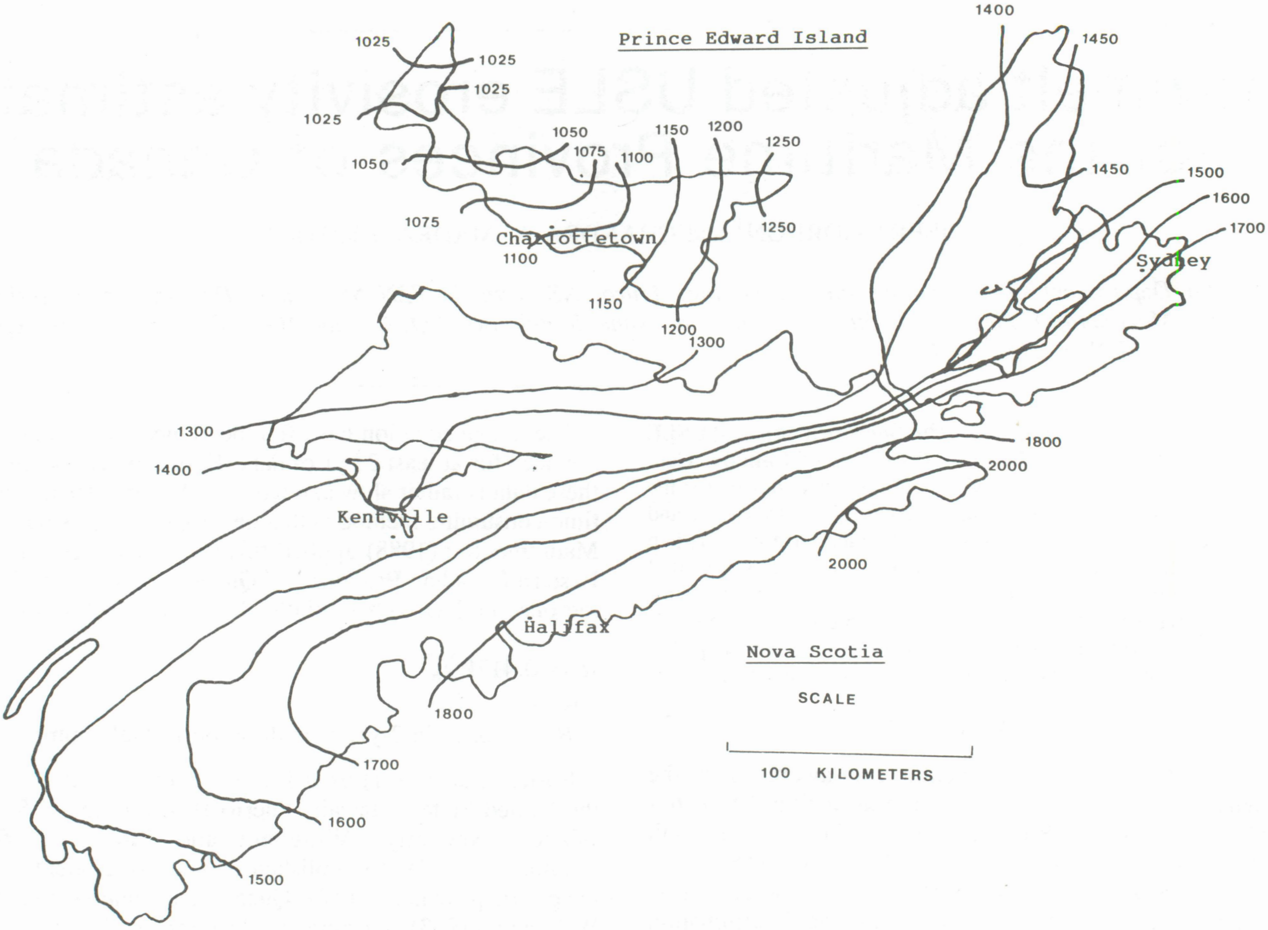

Fig. 1. Erosivity indices, winter adjustment not included, for Nova Scotia and Prince Edward Island (MJ mm ha^{-1} h^{-1} yr^{-1}).

The average annual R values were calculated for each of the grid points by using the results from the above calculations in conjunction with Eq. 3. Some of the estimated values were verified by comparing estimates of Wall et al. (1983). Isoerodent maps were then drawn from the above calculated grid points.

The average annual erosivity indices accounting for winter conditions were calculated using the long–term winter precipitation values from over 150 climatic stations in Nova Scotia, New Brunswick and Prince Edward Island and determining the percentages of cumulative winter precipitation (December to March) to the total annual precipitation. This method has been suggested and utilized by Wischmeier and Smith (1978), Wall et al. (1983) and Madramootoo (1988). The average annual erosivity indices, adjusted for winter conditions, were derived at each grid point from the following equation:

$$R_a = R\,(1 + WP/100) \qquad (5)$$

where:

R_a = average annual erosivity index adjusted for winter conditions (MJ mm ha^{-1} h^{-1} yr^{-1}),

WP = percentage of winter precipitation to the total annual precipitation (December-March),

R = average annual erosivity index (calculated from Eq. 3) (MJ mm ha^{-1} h^{-1} yr^{-1}).

Isoerodent maps based upon the above-mentioned average annual erosivity indices adjusted for winter conditions were drawn.

RESULTS AND DISCUSSION

Rainfall and runoff erosivity maps based on the average annual R values, not adjusted for winter conditions and adjusted for the winter conditions, are presented for Nova Scotia and Prince Edward Island in Figs. 1 and 2, respectively. Isoerodent maps for New Brunswick, not adjusted for winter conditions and adjusted for winter conditions, are shown in Figs. 3 and 4, respectively.

The R values observed in Fig. 1, for Nova Scotia range from approximately 1 300 MJ mm ha^{-1} h^{-1} yr^{1} from the Bay of Fundy in Cumberland County to the Northumberland Strait in Pictou County to 2 000 MJ mm ha^{-1} h^{-1} yr^{-1} along the Atlantic coast in Guysborough County. In the prime agricultural area of Nova Scotia, i.e., the Annapolis Valley region, R values range from 1 300 to 1 500 MJ mm ha^{-1} h^{-1} yr^{-1}. This represents the lowest values in the province. However, this area is still quite susceptible to significant soil erosion losses due to the high intensity of agricultural production, and the lack of protection of the soil. Also, many of the predominant soil types that exist in this area have a high percentage of silt in the surface horizon, leading to high erodibility. A high concentration of isoerodent lines exist near Chedubucto Bay where the values deviate by more than 500 MJ mm ha^{-1} h^{-1} yr^{-1} over a distance of 60 km, due to the high variability of extreme rainfalls in that area. Even though very little cultivated land exists, slopes in excess of 5% are common for most agricultural lands in Halifax and Guysborough counties resulting in a severe erosion risk potential for those areas in particular.

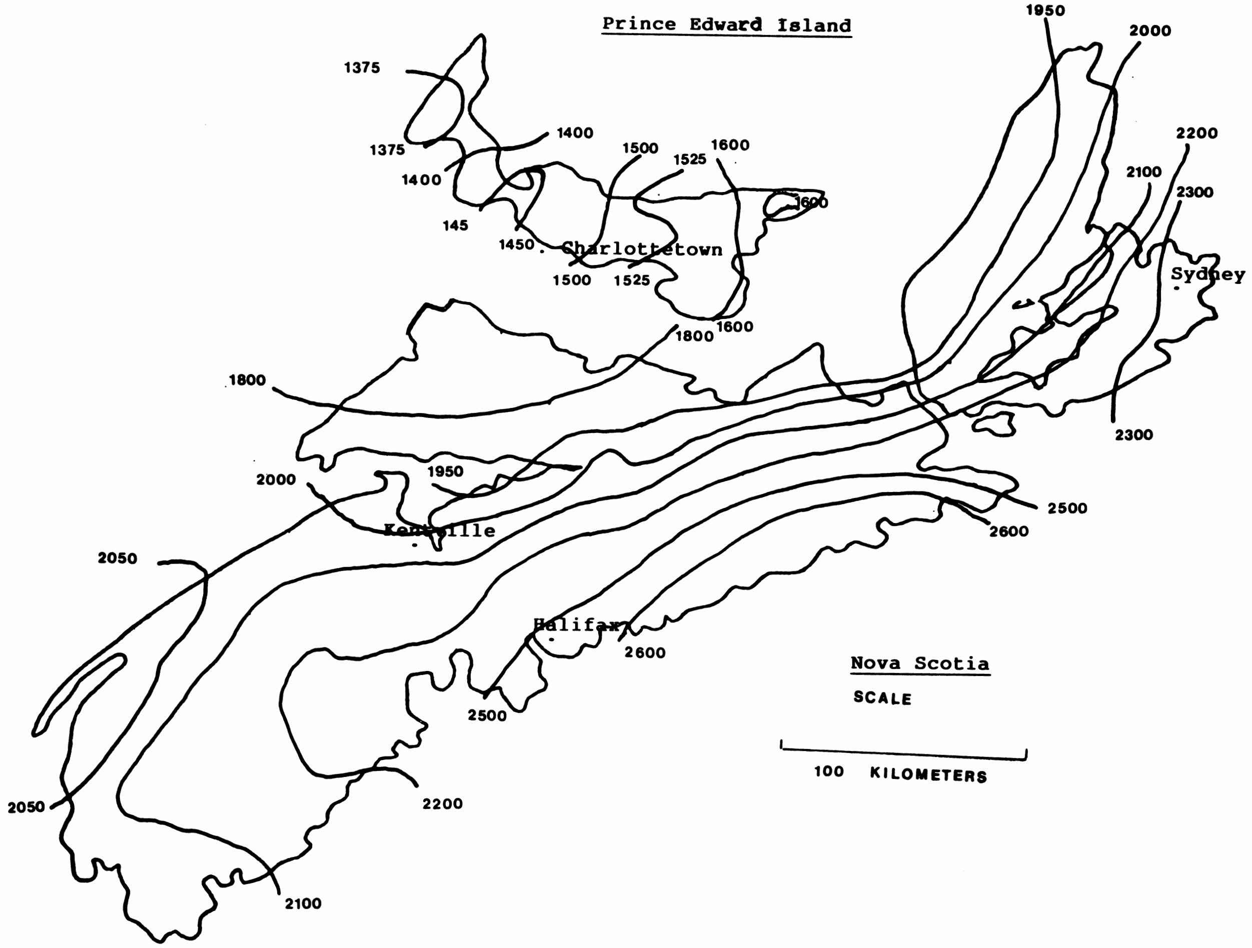

Fig. 2. Erosivity indices, winter adjustment included, for Nova Scotia and Prince Edward Island (MJ mm ha^{-1} h^{-1} yr^{-1}).

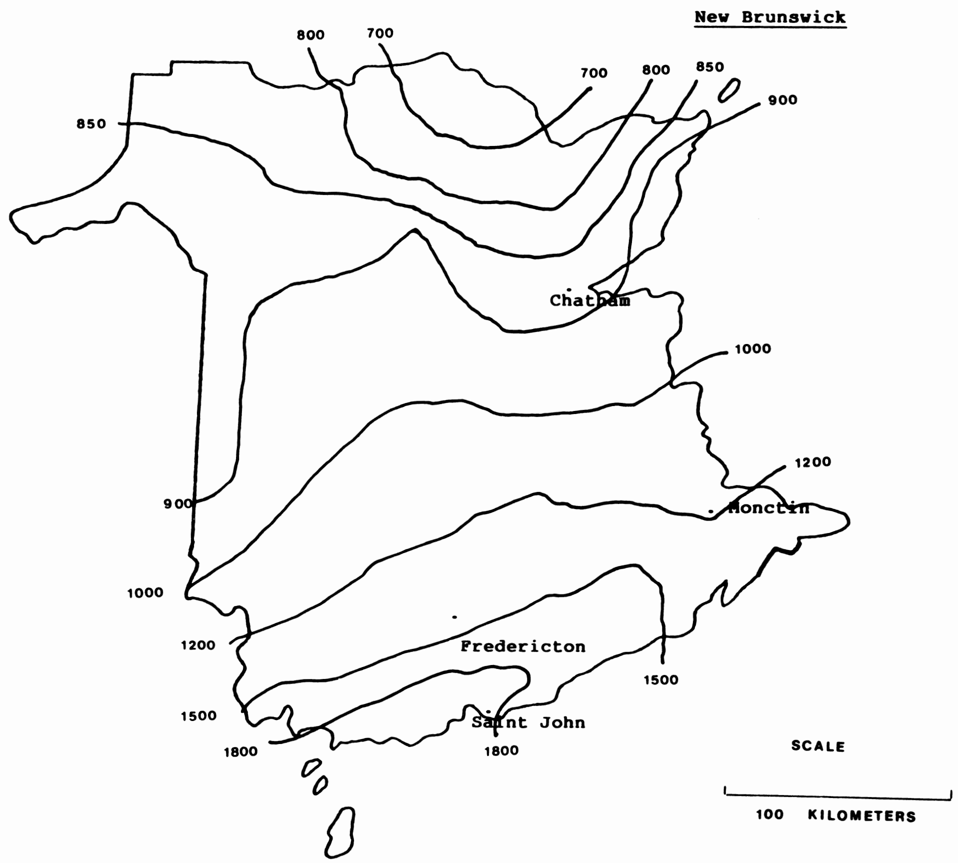

Fig. 3. Erosivity indices, winter adjustment not included, for New Brunswick (MJ mm ha^{-1} h^{-1} yr^{-1}).

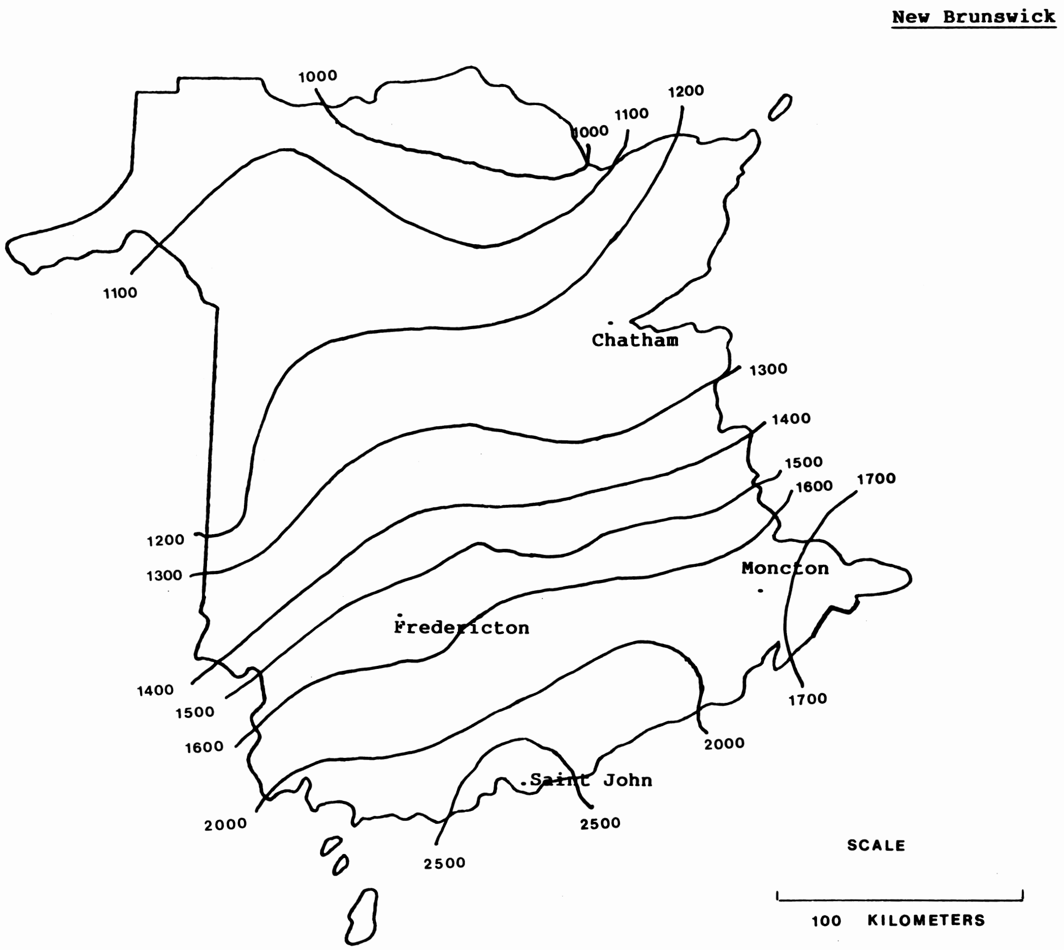

Fig. 4. Erosivity indices, winter adjustment included, for New Brunswick (MJ mm ha^{-1} h^{-1} yr^{-1}).

The R values in Prince Edward Island (Fig. 1) are highest among the east coast of the province (Kings county) near Souris where they reach 1 250 MJ mm ha^{-1} h^{-1} yr^{-1} (the highest values in Prince Edward Island are nearly equivalent numerically to the lowest in Nova Scotia). Cultivated slopes in this region are commonly in excess of 10%. The lowest values, approximately 1 025 MJ mm ha^{-1} h^{-1} yr^{-1}, are found along the west coast of the island from the western point of Egmont Bay to the Tignish Shore.

The R values in New Brunswick (Fig. 3) range from 700 MJ mm ha^{-1} h^{-1} yr^{-1} in the northern part of the province, near Campbellton, to 1 800 MJ mm ha^{-1} h^{-1} yr^{-1} along the Bay of Fundy coast from St. Andrews to Saint John. In these regions, slopes in excess of 10% are frequently cultivated for agricultural purposes, thus increasing the risk of soil erosion.

Higher winter erosivity indices (R_a) (Figs. 2 and 4) demonstrate the erosion potential due to rain and snowmelt on thawing ground. They vary from 1 000 MJ mm ha^{-1} h^{-1} yr^{-1} in the northern part of New Brunswick to 2 600 MJ mm ha^{-1} h^{-1} yr^{-1} along the eastern shore of Nova Scotia. This represents a 20 - 30% increase over the R values in Figs. 1 and 3.

Other methods of calculating winter erosion indices, such as that described by Williams and Berndt (1977), could have been employed. However, the same drawbacks exist in this study as were mentioned by Madramootoo (1988). Himelman and Stewart (1979) mentioned that the snowmelt period of March through April contributed significantly to the annual soil loss on erosion plots studied in Prince Edward Island. However in the Maritimes, freeze/thaw conditions prevail throughout the entire winter months contributing to significant soil loss due to snowmelt. In a laboratory study, Edwards and Burney (1987) examined soil losses under freeze/thaw conditionss from various Prince Edward Island soils. They found that inter-rill sediment loss was increased by 90% when freeze/thaw conditions occurred, but no increase in loss was observed under freeze/thaw conditions when the soil was seeded with a winter rye cover crop. This suggests that more research should be conducted in order to examine the relative effect of freeze/thaw conditions on various agricultural soils under various crop covers, and cultural practices.

Values predicted from Eq. 3 were close to those of Wall et al. (1983). For example, Wall et al. (1983) estimated R values of 1225 in Moncton and 1790 in Halifax. Equation 3 yielded values of 1200 for Moncton and 1800 for Halifax. This verified that the methodology presented in this paper is reliable. Winter erosivities calculated from Eq. 5 for Moncton and Halifax were 1700 and 2600, respectively.

CONCLUSIONS

Rainfall and runoff erosivity indices were calculated for the Maritime Provinces of Canada (Nova Scotia, New Brunswick and Prince Edward Island) using once-in-2-yr, 6-h rainfall data. They are the first detailed R values computed for these areas.

The spatial variability of the annual erosivity indices (not accounting for winter conditions) varied between 700 and 2000 MJ mm ha^{-1} h^{-1} yr^{-1}. The erosivity indices accounting for winter conditions varied from 1000 to 2600 MJ ha^{-1} h^{-1}

yr^{-1}. Snowmelt and runoff from unfrozen ground has been shown to significantly increase the erosion potential in many Canadian areas. This is also true for the Maritime Provinces where freeze/thaw snowmelt and runoff from unfrozen soils are commonly encountered. Future field studies in the Maritime Provinces are essential to account for winter conditions and their effect on application of the USLE.

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