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LONG-TERM CLIMATIC TRENDS FOR AGRICULTURE AT CHARLOTTETOWN, PRINCE EDWARD ISLAND

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INTRODUCTION

Climatic change has become an important issue in recent years. Many scientists now believe that temperatures will rise gradually as concentrations of carbon dioxide (CO_2), water vapor and other "greenhouse gases" (GHGs), such as methane and nitrous oxides, increase in the Earth's atmosphere. It is known that CO_2 concentrations have increased by about 25% since the start of the Industrial Revolution, mostly from burning fossil fuels and clearing forests. However, how much this rise in CO_2 has affected the Earth's average temperature remains unclear. Some scientific studies indicate that significant global warming has already occurred; others suggest it has not. In theory, global temperatures should have risen by about 0.5–1.3°C.

The "greenhouse effect" is an important natural phenomenon, without which the Earth would be more than 30°C colder than at present and essentially uninhabitable by humans. The GHGs in the atmosphere partly absorb or trap outgoing long-wave (infrared) radiation emitted from the Earth's surface. Water vapor is the most important GHG, absorbing most of the outgoing radiation. Warming from CO_2 is expected to increase evaporation and produce higher concentrations of water vapor, which in turn will likely lead to further warming.

Global warming is also expected to affect cloud cover. However, it is uncertain at present whether amounts of cloud will increase or decrease. Increased cloud cover would reflect more incoming solar radiation, causing cooler days, but would absorb more outgoing long-wave radiant heat, causing warmer nights. Evidence that cloud cover has increased over land areas in North America during the past 50 years or so may partly account for an observed decrease in day–night temperature range. However, we have no definite proof yet that the observed increase in cloud is caused by GHG warming. Ultimately, the effect of rising CO_2 on climate may not be known until the middle of the next century or later, by which time, depending on emission trends, CO_2 concentrations may have doubled.

Climatic changes also occur naturally, apart from any enhanced greenhouse effect resulting from human activity. For example, average global temperatures from 1100 to 1400 A.D. were as much as 0.5°C warmer than today. From the 1500s to the late 1800s, global temperatures were about 0.5°C cooler, which period climatologists have called the "Little Ice Age." Substantial year-to-year variations in climate at any given place cannot be considered as "climatic change" but simply as natural fluctuations of the climatic system.

This publication presents the climatic changes and fluctuations that have occurred over a 102-year period at Charlottetown, Prince Edward Island, Canada (lat. 46° 15' N, long. 63° 8' W). Examining trends over this period will help to show whether or

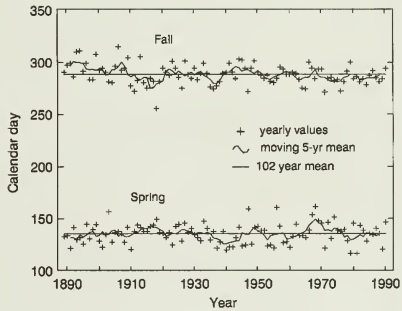

Fig. 1A Date of last spring and first fall frost (0°C), Charlottetown.

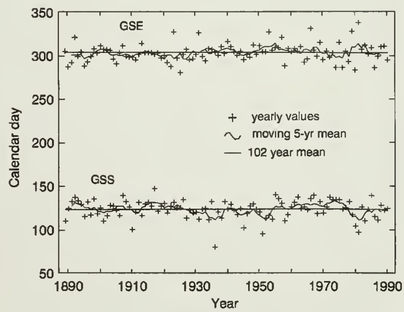

Fig. 1B Growing season start (GSS) and end (GSE), Charlottetown.

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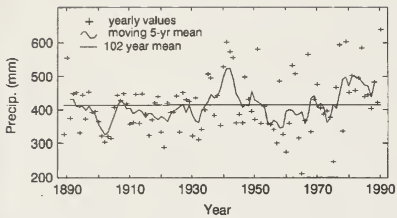

Fig. 1C Precipitation (May–September), Charlottetown.

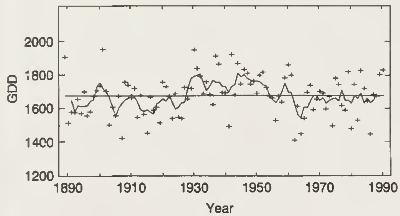

Fig. 1D Growing degree-days above 5°C (GDD), Charlottetown.

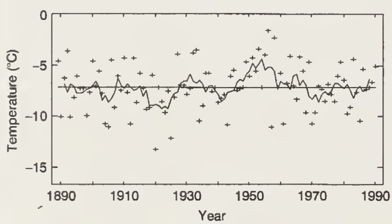

Fig. 1E January mean temperature, Charlottetown.

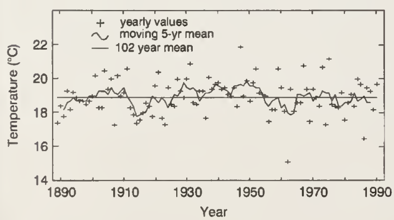

Fig. 1F July mean temperature, Charlottetown.

not climatic changes are taking place that affect crop production significantly in the Charlottetown area.

The study of climate at one particular place is not without its hazards. Apparent changes in climate can result from nonclimatic factors, such as subtle changes in station location, exposure or shelter, and observing practices. Urbanization can also affect the climatic record over the long term. Keep such effects in mind when interpreting long-term records.

CLIMATIC RECORD

The long-term climatic record at Charlottetown is very reliable in spite of some possible effects of urban growth of the city and its suburbs over the past century. Climatic records date back to 1872 at latitude 46° 14' N and 63° 10' W at an elevation of 12–14 m above sea level. Our analyses began with the year 1889. Observations began at the Experimental Farm in 1910 at an elevation of 23 m (latitude 46° 15' N, longitude 63° 08' W) and have continued up to the present, with relatively minor changes in observing practices and station location. No attempts were made to adjust data for urban influences or effects of changes in location or observing practices.

ANNUAL VARIABLES

We determined eight agroclimatic variables for each year from the daily record as follows: date of last spring frost of 0°C (SF); date of first fall frost of 0°C (FF); date of start of the growing season (GSS); date of end of the growing season (GSE); precipitation from May 1 to September 31 (P); growing degree-days above 5°C (GDD); January mean air temperature (JAN); and July mean air temperature (JUL).

We analyzed the variables SF, FF, GSS, and GSE in calendar days for convenience (Table 1). We determined GSS and GSE in each year by when the air temperature from a weighted 5-day mean stayed at or above 5.5°C (42°F) for 5 consecutive days in spring and the day it dropped below 5.5°C in fall, respectively. All other variables are self-explanatory, and Bootsma (1994) provides more details on how we computed them.

Table 1 Calendar day number for the last date of each month

Date	Calendar day*	Date	Calendar day
31 Jan.	31	31 July	212
28 Feb.	59	31 Aug.	243
31 Mar.	90	30 Sep.	273
30 Apr.	120	31 Oct.	304
31 May	151	30 Nov.	334
30 June	181	31 Dec.	365

* For leap year, add one calendar day to each date after Feb.

TREND ANALYSES OF ANNUAL DATA

We used the yearly variables to compute moving 5-year means over the 102 years. For example, the 5-year mean for 1920 includes the 1918–1922 data. We plotted yearly values and 5-year means for the eight variables (Figs. 1A–1F) in reference to the 102-year mean at Charlottetown (Table 2). Fig. 1A

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indicates no significant trend in the date of last spring frost over the period. There was a tendency toward earlier fall frosts over time, particularly since the 1960s. GSS and GSE do not show a significant trend toward earlier or later dates (Fig. 1B). Total precipitation from May to September (Fig. 1C) has tended to increase and become considerably more variable after the 1930s compared to earlier decades. This increased variability probably resulted in greater variation in crop yields in later years in the Charlottetown area.

There was no consistently increasing or decreasing trend in GDD over the full 102-yr period (Fig. 1D); however, 5-year moving averages indicate a tendency to above-average values from 1930 to 1960, with near normal values (1680 GDD) in the last 2 decades. January and July mean air temperature (Figs. 1E and 1F, respectively) do not indicate significant warming or cooling. Even though scientists expect the CO_2 warming effect to be greatest during winter in northern latitudes, there is no evidence that January temperatures are becoming milder at Charlottetown.

The lack of warming evidence does not prove that global warming has no effect on the climate at Charlottetown. Global warming, as well as other factors, may cause changes in large-scale weather circulation patterns such that some locations could actually become cooler. Any warming effects that may have occurred as a result of urban growth at Charlottetown appear to have been offset by other cooling factors.

CUMULATIVE FREQUENCIES OR PROBABILITIES

To determine if the last 30-year period (1961–1990) has been unusual in comparison to the 102-year pattern, we plotted cumulative frequencies or probabilities for all eight variables for both periods at Charlottetown (Figs. 2A–2F; vertical lines represent mean values from Table 2). In Figs. 2A and 2B, the left axes indicate the probability of experiencing later values in spring and earlier values in fall than shown in the graph; the right axes show the probability of Charlottetown experiencing earlier values in spring and later values in fall. For example, there exists about a 95% probability (95 years in 100, or 19 years in 20) that the GSS is on or after day 100 or April 10 (Fig. 2B). Alternatively, there is about a 5% probability that the growing season starts before April 10 (5 years in 100 or 1 year in 20). Period of record had only marginal influence on spring and fall frost dates and start and end of the growing season (Figs. 2A and 2B, Table 2), as average values differed at the most by 3 days or less.

In Figs. 2C–2F, the left hand axis indicates the probability with which lower values occur and the right hand axis indicates probability of higher values. May–September precipitation over the past 102 years (Fig. 2C) has increased significantly, although not always steadily (Fig. 1C). Average values for the last 30-year period are 27 mm (6.5%) higher than the 102-year mean (Table 2). GDD accumulated over the growing season are only marginally different for the two periods, with average values down 25 GDD in the last 30 years. Mean temperatures for January and July (Figs. 2E and 2F) show little change in probability for the two periods.

Table 2 Comparison of mean values of agroclimatic variables for 1889–1990 and 1961–1990 at Charlottetown

Variable	1889–1990 mean	1961–1990 mean
Date of last spring frost (SF)	15 May	17 May
Date of first fall frost (FF)	15 Oct.	15 Oct.
Start of growing season (GSS)	3 May	5 May
End of growing season (GSE)	30 Oct.	31 Oct.
Growing degree-days >5°C (GDD)	1679	1654
May–Sept. precipitation (P) (mm)	415	442
January mean air temp. (JAN)(°C)	–7.2	–7.3
July mean air temp. (JUL)(°C)	18.9	18.8

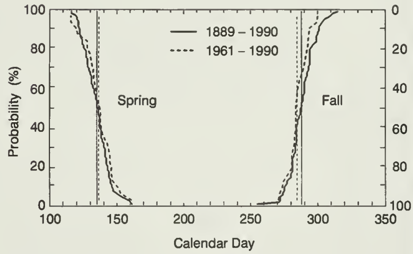

Fig. 2A Probability of last spring and first fall frost (0°C), Charlottetown.

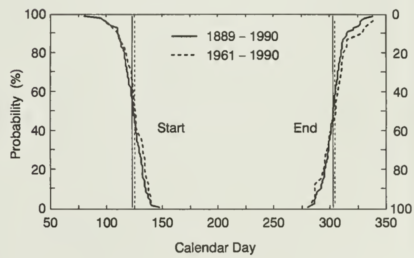

Fig. 2B Probability of start and end of growing season, Charlottetown.

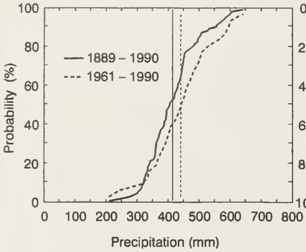

Fig. 2C Probability of precipitation (May–September), Charlottetown.

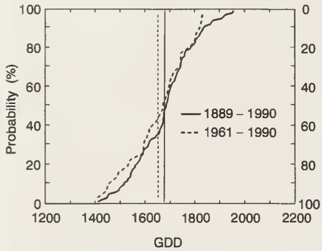

Fig. 2D Probability of growing degree-days above 5°C (GDD), Charlottetown.

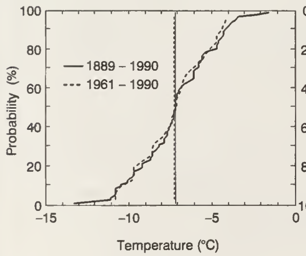

Fig. 2E Probability of January mean temperature, Charlottetown.

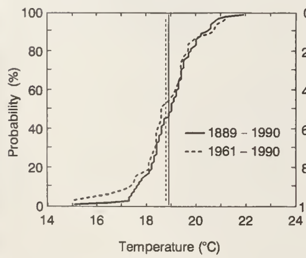

Fig. 2F Probability of July mean temperature, Charlottetown.

CONCLUSION

Temperature-related factors of importance to agriculture have not changed significantly over the past 102 years at Charlottetown. There was, however, a tendency toward above normal growing degree-days in the 1930s and 1940s. Although May–September rainfall has increased in amount and variability during the last 50 years or so, the two driest growing seasons on record both occurred in the last 30 years. Increased variability in precipitation (P) has likely resulted in more variation in crops yields, although no data are presented that prove this is so. The increase in precipitation variability needs to be confirmed by comparisons with other stations in the region as there remains a possibility that this could have been affected by changes in instruments or location over the years.

Global warming apparently has had little, if any, effect on climatic conditions influencing agriculture at Charlottetown over the past 102 years. Nevertheless, long-term global climate change still may be expected to have an effect on climatic patterns for Island agriculture in future. We do not know exactly how far the Charlottetown results can be extended to the region. However, we expect similar results within at least a 100-km radius of Charlottetown.

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REFERENCE

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