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LONG-TERM CLIMATIC TRENDS FOR AGRICULTURE AT AGASSIZ, BRITISH COLUMBIA

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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.

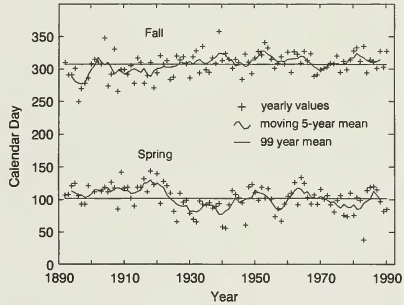

Fig. 1A Date of last spring and first fall frost (0°C), Agassiz.

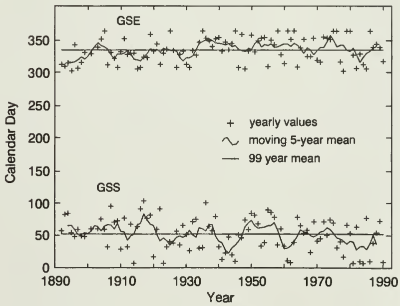

Fig. 1B Growing season start (GSS) and end (GSE), Agassiz.

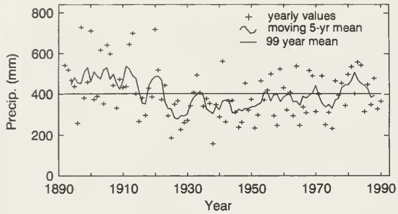

Fig. 1C Precipitation (May–September), Agassiz.

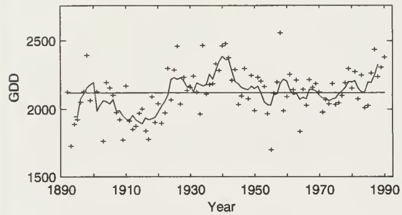

Fig. 1D Growing degree-days above 5°C (GDD), Agassiz.

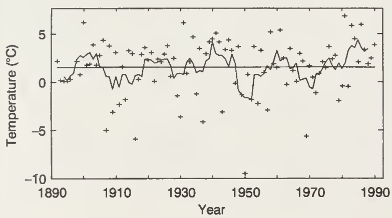

Fig. 1E January mean temperature, Agassiz.

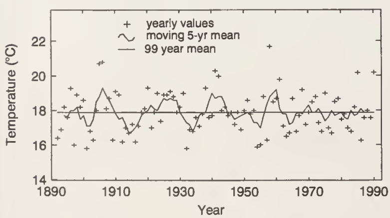

Fig. 1F July mean temperature, Agassiz.

This publication presents the climatic changes and fluctuations that have occurred over a 99-year period at Agassiz, B.C., Canada (latitude 49° 15' N, longitude 121° 46' W). Examining trends over this period will help to show whether or not climatic changes are taking place that affect crop production significantly in the Agassiz 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 Agassiz may be considered quite reliable. However, there is evidence that daily maximum temperatures were significantly higher and minimums significantly lower compared to other stations in the area for the period before the mid 1920s (D. Spittlehouse, personal communication). This casts some doubt on the reliability of the early records. Nevertheless, for this study, we used daily records from 1 January 1892 to 31 December 1990. The station latitude, longitude, and elevation have remained the same, despite slight changes in location. In recent years, observations have been made using both manual and automated systems. The station is located on the north edge of the town of Agassiz. Increase in local population has been small and therefore it is unlikely that local urban growth has affected the climatic record. The station may have experienced some urban influence from the greater Vancouver area, but extent of this influence is not known.

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

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.

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.

TREND ANALYSES OF ANNUAL DATA

We used the yearly variables to compute moving 5-year means over the 99 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 99-year mean at Agassiz (Table 2). Fig. 1A indicates a slight tendency toward earlier spring and later fall frost dates over time. Statistical tests likewise indicated earlier GSS and later GSE over time (Fig. 1B), although again the trends are small. Total precipitation from May to September (Fig. 1C) has tended to decrease and become less variable after the 1930s compared to earlier decades. Fluctuations in P were quite large, ranging from a low of 158 mm in 1938, to a high of 729 mm in 1897. GDD increased from the early 1900s to about 1940, dropping again to the mid 1970s and rising to well above the average in the last decade (Fig. 1D).

January and July mean temperatures have not changed significantly (Figs. 1E and 1F). Scientists expect the "greenhouse" effect to result in greater warming during winter than in summer at high latitudes. However, the fact that January temperatures have not become milder does not prove that global GHG warming has had no influence on the climate at Agassiz. Other researchers have found that average temperatures for December–March at Agassiz have increased by 0.9°C over this period (K. Perry, Atmospheric Environment Service, Pacific Region, personal communication). It is also possible that global warming could cause changes in large-scale weather circulation patterns such that some areas will actually become cooler during certain periods of the year.

CUMULATIVE FREQUENCIES OR PROBABILITIES

To determine if the last 30-year period (1961–1990) has been unusual in comparison to the 99-year pattern, we plotted cumulative frequencies or probabilities for all eight variables for both periods at Agassiz (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 Agassiz experiencing earlier values in spring and later values in fall. For example, there exists about a 10% probability (1 year in 10) that the last spring frost occurs on or after day 125 (May 5). Alternatively, there is about a 90% probability that the date of last spring frost occurs on or before this date. Period of record had only slight influence on spring and fall frost dates (Fig. 2A). The start of the growing season was advanced by 8 days for the last 30-year period (Fig. 2B, Table 2), while the end of the growing season was only slightly affected.

Table 2 Comparison of mean values of agroclimatic variables for 1892–1990 and 1961–1990 at Agassiz

Variable	1892–1990 mean	1961–1990 mean
Date of last spring frost (SF)	12 Apr.	10 Apr.
Date of first fall frost (FF)	7 Nov.	8 Nov.
Start of growing season (GSS)	21 Feb.	13 Feb.
End of growing season (GSE)	30 Nov.	3 Dec
Growing degree-days >5°C (GDD)	2118	2153
May–Sept. precipitation (P) (mm)	402	397
January mean air temp. (JAN)(°C)	1.6	2.0
July mean air temp. (JUL)(°C)	17.9	17.9

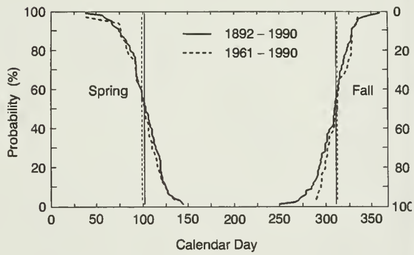

Fig. 2A Probability of last spring and first fall frost (0°C), Agassiz.

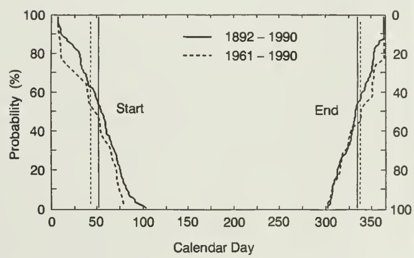

Fig. 2B Probability of start and end of growing season, Agassiz.

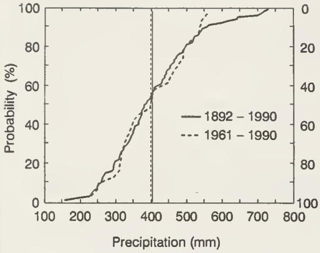

Fig. 2C Probability of precipitation (May–September), Agassiz.

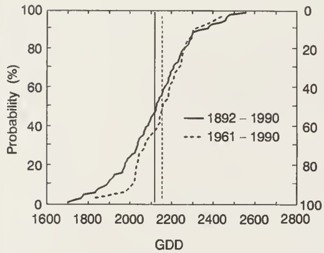

Fig. 2D Probability of growing degree-days above 5°C (GDD), Agassiz.

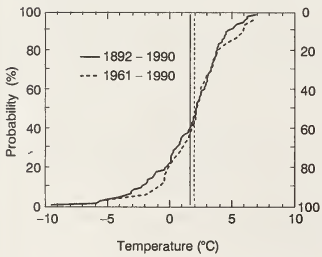

Fig. 2E Probability of January mean temperature, Agassiz.

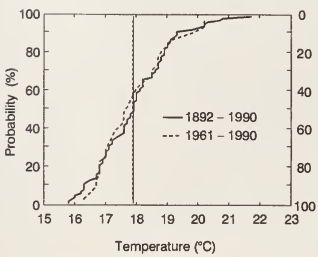

Fig. 2F Probability of July mean temperature, Agassiz.

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 (Fig. 2C) has not changed significantly over 99 years. Average values for the 30-year period are only 5 mm lower than the 99-year mean (Table 2). However, the chances of getting extremely wet years (more than 550 mm) appears to have decreased significantly in the last 30 years (Fig. 2C). GDD accumulated over the growing season are slightly higher for the 30-year period, with average values up 35 GDD from the 99-year mean (Fig. 2D, Table 2). Mean temperatures for January and July (Figs. 2E and 2F) did not change significantly from the 99-year pattern in the last 30 years.

CONCLUSION

There is evidence that slight, although significant, warming has occurred during the growing season at Agassiz during the past century. This may be partially due to global GHG warming, changes in large-scale weather circulation patterns, or other unidentified factors. More research into identifying the causes of climatic shifts would be useful for forecasting climate. Because the relatively rapid changes in climate that occur with distance in the Fraser Valley, it is unsafe to extrapolate these results to other locations in the Valley without further study. Similar warming trends have been observed at other locations in western Canada, i.e., Indian Head and Brandon (Bootsma 1994).

ACKNOWLEDGMENTS

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REFERENCE

Bootsma, A. 1994. Long term (100 year) climatic trends for agriculture at selected locations in Canada.Climate Change 26:65–88.

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