Implications of Climate Change on Prairie Agriculture

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Abstract

The Implications of Climate Change on Prairie Agriculture study is a work in progress which is funded by the Prairie Adaptation Research Cooperative (PARC) and presently being completed by the Prairie Farm Rehabilitation Administration (PFRA). The objective of this project is to determine the impact of climate change on the current farming practices with the various landscapes of the prairies. It compares 1961-1990 (30 year mean) climate normals and 2040-2069 (30 year mean) climate model predictions. Data are used from current climate stations for the 1961-90 period and from the Canadian Global Circulation Model (CGCM1) for the 2040-69 period. The Land Suitability Rating System and the Soil Landscapes of Canada will be used to rate the land based on climate, soils and landscape parameters specified. These results will be applied to the Prairie Agricultural Landscapes (PAL) study, completed by PFRA in 2000, which identified unique relationships between farming practices and landscapes across the agricultural landbase of the prairies. Taking a landscape-based approach will provide a better understanding of the sustainability of the current agricultural system with climate change predictions.

Introduction

"Since the settlement of the prairies in the 19th and early 20th centuries, land use and farming practices have evolved to match the various climates and soil types on the prairies and adapted to changing markets, technology and transportation systems. The abandonment of farms in the Special Areas of Alberta during the early 1920s and southwestern Saskatchewan in the 1930s, provides evidence of these adjustment processes. More recently, since the 1980s, there has been a reduction in summerfallow and an expansion of crop varieties, particularly in areas of higher moisture." (PFRA 2000)

This statement from the Prairie Agricultural Landscapes (PAL) report by PFRA reinforces the need for continued study on the impact of climate change affects on agricultural systems. Besides the social and economic factors, soil, land form, vegetation and climate factors contribute greatly to the limitation of agricultural systems to change (Dumanski and Kirkwood 1988; Huffman et al. 1993).

Using the most current climate models developed by the Canadian Institute for Climate Studies (CICS), PFRA is conducting a study to determine the implications of climate change on prairie agriculture. This study will use the Soil Landscapes of Canada and the land practices groups derived from the PAL study to determine the impact of climatic scenarios on economic and environmental conditions within the land practices groups.

The study compares the 1961-1990 (30 year mean) climate normals and the 2040-2069 (30 year mean) climate model predictions. The 1961-90 climate data are collected from current climate stations. The 2040-69 climate data are derived from the Canadian Global Circulation (Greenhouse Gas with Aerosol Simulation) Model. This model has a gridded spatial resolution of 3.75 degrees latitude by 3.75 degrees longitude. Agro-climatic parameters derived from this data were input into the Land Suitability Rating System (LSRS) to determine changes in climate rating between these two periods.

Methodology

Data Sources

The Canadian Institute for Climate Studies (CICS) and the Meteorological Service of Canada are leading a project called the Canadian Climate Impacts Scenarios (CCIS). This project is funded by the Climate Change Action Fund and is meant to provide a Canadian perspective on climate change scenarios for impacts researchers (University of Regina, unpubl.). The Global Circulation Model experiments are all warm-start, (ie., the forcing due to greenhouse gases and aerosols over the historical period) (University of Regina, unpubl.). The CICS web site (www.cics.uvic.ca/scenarios/) offers three IPCC-recommended future time period scenarios: the 2020s (2010-2039), the 2050s (2040-2069) and the 2080s (2070-2099). A mean 30-year period is used as the base time period for the scenarios to ensure that the climate change signal is concentrated with the inter-decadal variability reduced. (University of Regina, unpubl.). The 2050s period was chosen for this study because it represents the future, but not too distant.

Output data are offered by CICS for various scenarios including the Canadian Global Circulation Model (CGCM1) from the Canadian Centre for Climate Modelling and Analysis (CCCMA) and the Hadley model (HadCM2) from the United Kingdom's Hadley Centre for Climate Prediction and Research. Other models available are: ECHAM4 from Germany, GFDL-R15 from the United States, CSIRO-Mk2b from Australia, or CCSR-98 from Japan (University of Regina, unpubl.).

Based on research completed by the University of Regina and the Prairie Adaptation Research Cooperative, the Canadian model (CGCM1) was recommended for use in this study. The recommendations were based on several factors (University of Regina, unpubl.). The model was used by the United States National Academy of Science in its climate change assessment. As well, the model climate predicted is considered to be quite stable, having little residual drift and the mean global temperatures, sea level pressure patterns and atmospheric circulation simulations are considered close to reality. Lastly, the general characteristics of the present baseline climate were considered to be well modelled (Hengeveld 2000).

The Agriculture and Agri-Food Canada (AAFC) Research Branch and the Canadian Forest Service (CFS) have used the CGCM1 output data from CCCMA to compute the climate parameters: maximum and minimum temperature and precipitation as well as the climate indices (precipitation minus potential evapotranspiration (P-PE) and Effective Growing Degree Days (EGDD)) for the 2050 period (Bootsma, unpubl.). They have computed the same parameters for the 1961-90 baseline period from the current climate stations. For data comparison they have interpolated both the 61-90 climate station data and the 2050 model data to a 10km grid

(Bootsma, unpubl.). PFRA has converted the 10km grid data to points (centroids) and averaged their climate parameters for each Soil Landscapes of Canada (SLC) polygon. In doing this, PFRA has created data results to map maximum temperature and precipitation values as well as the moisture deficit(P-PE) and temperature factor (EGDD) values used in the Land Suitability Rating System (LSRS).

Land Suitability Rating System

The LSRS is used to rate the suitability of land for spring seeded small grains (Agronomic Interpretations Working Group 1992). This system was developed in the early 1990s to replace the Canada Land Inventory (CLI). The LSRS retained the CLI seven class system to classify land. Class 1 land has the highest suitability or least limitations and Class 7 land, the lowest suitability or greatest limitations (Agronomic Interpretations Working Group 1992).

The LSRS is comprised of three components (climate, soils and landscape) which determine the suitability of land for crops. Each component is rated separately and is assigned a value between 0 and 100. The final land suitability rating is determined by the most limiting of the three components (Agronomic Interpretations Working Group 1992). The work completed to date on this project has only examined the climate class limitation. The LSRS climate class limitation uses the subclasses of “A” and “H”. “A” indicates a moisture limitation required for optimal growth of crops, while “H” represents a heat units limitation required for optimal growth of crops (Agronomic Interpretations Working Group 1992).

The main data sources used for running the LSRS are a soil component file, soil names file, soil layers file, and a climate file. The soil component, names and layer files have all been supplied by pedologists from the Western Land Resource Group of the Agriculture and Agri-Food Research Branch and are based spatially on the Soil Landscapes of Canada. As mentioned previously, the climate data component of the LSRS has been supplied by the Agriculture and Agri-Food Research Branch and the Canadian Forest Service.

Results and Conclusions

The results achieved for the temperature and precipitation maps are based on mean annual values for the 1961-90 and 2050 periods. The temperature change for 2050 is the absolute difference from the 61-90 values. The 2050 precipitation was calculated as a ratio value then converted to an absolute change value from the 61-90 period (Bootsma, unpubl.).

The 1961-90 data displays a mean annual maximum temperature ranging between –1.5 C and 12 C for the prairie provinces. The highest temperatures appear mainly in southern portions of Alberta and Saskatchewan in the 9-12 C range. The 2050s mean annual maximum temperature change predicts absolute changes of 2.15-4.25 C across the prairies. The temperatures increase the most in the southern portions of the provinces, especially in Saskatchewan and Manitoba where the values are between 3.5-4.25 C.

The 61-90 data for mean annual precipitation ranges between 285 and 600mm for the prairies. For the majority of the agricultural area of Alberta and Saskatchewan the values are 285-450mm with Manitoba at 450-600mm. The change for the 2050s period suggests relatively small increases in precipitation ranging from only 3.75-75mm prairie-wide, with the large majority of the agricultural area falling in the 3.75-30mm precipitation increase only.

The moisture deficit and temperature factor are the two main indices used in computing the Land Suitability Rating System climate component. The moisture deficit is a measure of precipitation minus potential evapotranspiration (P-PE) (Agronomic Interpretations Working Group 1992). The more negative the P-PE value the drier the condition. To date, no modifying factors such as excess spring and fall moisture or fall frost have been taken into account.

The moisture deficit and temperature factor calculations are based on the growing season period which begins 10 days after the mean temperature is >= 5 C in spring and ends the day before the average date of the first fall frost (first occurrence of minimum temperature <= 0 C) (Bootsma, unpubl.). The P-PE values for 61-90 are from –450 to +50 over the entire area of the prairies. The areas of southern Alberta and Saskatchewan range mainly between –450 and –350, with southern Manitoba at –300 to –200. The 2050 period results suggest a dramatic change in the deficit values. The majority of the southern portions of the prairies are mainly between –610 and –400 with the more northern extents of the area ranging between –400 and –200.

The temperature factor, as mentioned, is based on the Effective Growing Degree Day (EGDD) calculation. The value is calculated from the length of season, degree days, and day length, taking into account a longer day length at higher latitudes (Bootsma, unpubl.). The higher the value the longer the growing season. The EGDD values for the 61-90 period range between 50 and 500 in parts of western Alberta up to 1400 to 1650 in the southern areas of the prairies. In general, most of the agricultural area falls in the 1200-1650 range. For the 2050 period, the modelled values predict that the temperature factor is allowing for a longer growing season with warmer temperatures. In most portions of the agricultural area of the prairies values will be pretty much all at 1650 and above, up to as high as 2400 Effective Growing Degree Days.

Therefore, increasing temperatures and reduced amounts of precipitation appear to be triggering the moisture deficit to be greater (drier) and the growing season considerably longer according to the CGCM data results. When these values are input into the LSRS dramatic changes are reflected in climate ratings for the prairie agricultural area. The 61-90 map displays considerably large portions of the agricultural area as being class 2A (moisture limitation) and 3A with some 2H (heat units limitation) and 3H areas and a small area of Manitoba as class 1. The 2050 results predict dramatic changes. Large portions of the southern agricultural area have changed to classes 4A up to 6A and even 7A. The majority of Manitoba's agricultural area, as well as the northern extents of Saskatchewan's agricultural area are classed as 3A. In Alberta there is some class1 and 2A. In addition, the LSRS rating has also shifted the climate to class 1 for large portions of the northern areas of the prairies as well, which are not in the agricultural area.

At this stage in the project's development, it can then be concluded that the CGCM predicts dramatic changes when run in the LSRS. However, it is important to note that the purpose of this exercise is to interpret what the climate model tells us about the capability for agriculture, not to fully endorse its results. In using this model we will obtain an indication of possible implications of climate change on prairie agriculture.

Future use of this type of information would include application to the Prairie Agricultural Landscapes (PAL) study completed by PFRA. The PAL study has identified unique relationships between farming practices and landscapes over the agricultural landbase of the prairies. Relating climate change scenario results to this established study will identify the landscapes and land practices that are most susceptible to climate change on the prairies offering a greater understanding of the sustainability of the current agricultural system.

It is important to remember that this is a possible climate change scenario, not a forecast. This exercise has created a process to move from the model to examining the implications of the model through a land resource framework such as the Land Suitability Rating System. It has provided for a methodology to be in place for evaluating the impacts of other models for comparison. Finally, in addressing the project objectives, it allows for this to be used as a common testing ground to further discuss the possible implications of climate change and how to possibly begin formulating adaptation strategies to climate change.

Requests for maps are available by contacting: nyirfaw@em.agr.ca

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