IMPACTS OF CLIMATE CHANGE ON AGRICULTURE IN NOVA SCOTIA

by

Emma-Lee S. Adlakha

Thesis submitted in partial fulfillment of the
requirements for the Degree of
Bachelor of Arts with
Honours in Economics

Acadia University
April, 2011

This thesis by Emma-Lee S. Adlakha
is accepted in its present form by the
Department of Economics
as satisfying the thesis requirements for the degree of
Bachelor of Economics with Honours

Approved by the Thesis Supervisor

Professor Scott Skjei Date

Approved by the Head of the Department

Dr. Paul Hobson Date

Approved by the Honours Committee

Dr. Sonia Hewitt Date

I, Emma-Lee S. Adlakha, grant permission to the University Librarian at Acadia University to reproduce, loan or distribute copies of my thesis in microform, paper or electronic formats on a non-profit basis. I, however, retain the copyright in my thesis.

Signature of Author

Date

Acknowledgments

This thesis would not have been possible without the valuable contribution of several people. Professor Scott Skjei’s commitment, patience, and guidance have been crucial throughout this whole process and it is greatly appreciated. Dr. Burc Kayahan’s input and availability are also appreciated. My parents’ efforts to be interested in what I am researching and believing I could accomplish this are also highly valued and appreciated.

Table of Contents

List of Tables

Chapter 6:

List of Figures

Chapter 3:

Chapter 6:

Abstract

In this analysis, the impact of climate change on agriculture in Nova Scotia is estimated. Using the Ricardian method of analysis, climate variables are regressed on the value of farmland in the province of Nova Scotia.

The regression output produced from the relationship of climate variables and the value of farmland is found to be suffering from the phenomenon of autocorrelation. Once the regression output is corrected for autocorrelation, the regression is ran again and agriculture in Nova Scotia is found to be unaffected by increasing temperatures and increasing amounts of precipitation.

Chapter 1: Introduction

Although climate change is expected to have many impacts on various sectors of the economy, few sectors are as important as agriculture (Mendelsohn & Dinar, 2009). According to the Nova Scotia Federation of Agriculture (2009), Agriculture is a key industry to Nova Scotia because of its contribution to the economy, its role in sustaining rural communities, the food security it provides, and its contribution to health and the environment. The agriculture and agri-food sector is also an important source of income and employment in provincial economies; the sector contributes approximately 3 percent to Nova Scotia's GDP and accounts for about 11 percent of Nova Scotia's employment (Agriculture and Agri-food Canada, 2008). According to Natural Resources Canada, future climate changes projected by the Intergovernmental Panel on Climate Change would result in advantages and disadvantages for the agricultural sector in Canada, varying on a regional basis (Natural Resources Canada, 2004). For Nova Scotia the average temperature rose by half a degree (Celsius) in the 20th century and is expected to rise by another 2 to 4 degrees (Celsius) in the 21st century (Nova Scotia Department of Environment, 2009).

Chapter 2: Climate Change

Because the work in this paper discusses the impacts arising from climate change, the definition of climate change is essential to fully understand such impacts.

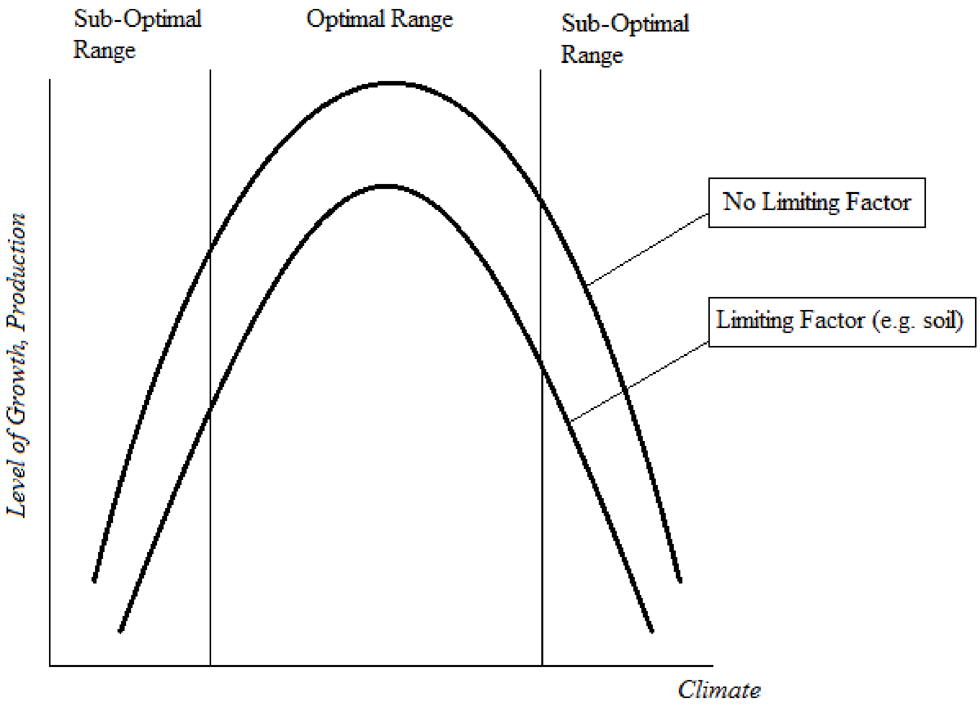
I define climate change as the change in temperature and weather patterns over a period of time. The causation for climate change is attributed largely to the increased levels of atmospheric carbon dioxide produced by the human activity of the burning of fossil fuels (Oxford Dictionaries, 2010). Although there are natural forces, such as volcanic shifting, solar activity, and orbital changes that also contributed to climate change; human activity is largely the prevailing force (Government of Canada, 2010).

The burning of fossil fuels release what are known as greenhouse gases into the atmosphere. Greenhouse gases are gases in the Earth’s atmosphere that absorb heat energy radiated by the earth and return most of this energy back towards the surface. This process is known as the greenhouse effect (Government of Canada, 2010). Greenhouse gases stay in the atmosphere for long periods of time. With fossil fuels constantly being burned, the concentration of the greenhouse gases continue to rise, trapping increasing amounts of heat in the earth’s atmosphere and resulting in an increase of the earth’s temperature over time (Mendelsohn & Dinar, 2009).

Chapter 3: Role of Climate Change in Agriculture

According to Mendelsohn and Dinar (2009), there is sufficient evidence to suggest that climate change will affect agriculture. They suggest an optimal climate range of temperature and precipitation exists for crop and livestock production. Mendelsohn and Dinar (2009) also say there are factors that change the optimal range of growth and production with respect to climate, such factors are soil and water. For example, poor soil and not enough water will not allow crops to grow and produce at the level they could with better quality soil and more water (Mendelsohn & Dinar, 2009).

Figure 3.1 Climate and Soil Interaction on Growth and Production of Crops and Livestock.



Source: Mendelsohn and Dinar 2009

Figure 3.1 is a representation of the relationship between climate ranges (of combinations of temperature and precipitation) and the level of growth and production in crops and livestock. The middle section of the graph, the line without the limiting factor, represents the optimal range of climate variables where crops and livestock are able to yield maximum growth and production. The lower line in Figure 3.1 shows the relationship between climate and growth and production when there are limiting factors such as poor soil and no water. Although on this limiting line there is an optimal range, the limiting factors prevent crops and livestock from growing and producing at their maximum levels obtained at the line without limiting factors.

Crops and livestock each have unique ways of responding to changing climate variables because each has its own way in which it grows and produces.

Plants have become specialized to optimize yields at particular temperature and humidity settings (Morison, 1996). The level of CO_2 and temperature in the atmosphere affect the rate at which a plant develops. With the increasing of temperatures and the concentration of CO_2 rising, the rate of development in plants changes, in turn affecting the growing period of the plant or crop (Mendelsohn & Dinar, 2009).

Livestock growth and production also has an optimal range of climate conditions although the growth and production of livestock in Canada and thus Nova Scotia does not face the problems of climate change (Mendelsohn & Dinar, 2009). The livestock growth and production in Nova Scotia takes place within optimal controlled settings, shelter and sufficient nutrients, where the suboptimal climate can be compensated with proper amounts of food and water (Mendelsohn & Dinar, 2009).

Chapter 4: Theory

The work in this paper is primarily based on the research completed by Dr. Robert Mendelsohn and Dr. Michelle Reinsborough on the Ricardian analysis of US and Canadian farmland (2007). The model used to measure the effects of climate change on agriculture in Nova Scotia is the Ricardian method (Mendelsohn et al, 1994).

The Ricardian method regresses the value of farmland per acre, on climate and other exogenous variables to show how changes in climate explain the value of farmland. The relationships produced can then be used to predict agricultural impacts of changes in climate in the future (Mendelsohn & Reinsborough, 2007). An assumption made by the Ricardian method is farmers chose a set of inputs and outputs to maximize their profits when constrained with exogenous factors they cannot control, such as climate (Mendelsohn & Reinsborough, 2007).

An advantage the Ricardian method possesses is that it includes efficient adaptations made by farmers in response to climate change by capturing how farmers modify their methods of production in response to changes in temperature, rainfall, and water availability (Mendelsohn & Dinar, 2009). It is important to note that the adaptations made by farmers included in the model are current adaptations; the Ricardian method does not predict future adaptations as farmers' ability to adapt changes with changing technology, input and output prices, and human capital (Mendelsohn & Dinar, 2009).

The Ricardian method also possesses some disadvantages. The impact of important variables, such as irrigation, that could attribute to the explanation of variation in farm value is not fully controlled for in the Ricardian method (Mendelsohn & Dinar, 2009). Prices are assumed to be constant in the Ricardian method when prices could change, creating the possibility of bias estimates that could overestimate the damages and benefits from climate change (Mendelsohn & Dinar, 2009).

The Ricardian model used and based on the work by Mendelsohn and Reinsborough (2007) is as follows:

$$V = B_0 + B_1T + B_3P + B_6Z + u$$

where V represents the dependent variable farmland value, T is a vector of seasonal temperatures, P is a vector of seasonal precipitation, Z is a vector of the other exogenous variables, and u is the error term.

Chapter 5: Data

The farmland value data for the years 1981-2009 came from Statistic Canada's socioeconomic database, CANSIM. The CANSIM database also provided the population data on change, density, and income (Statistics Canada 2005, 2006). The climate data was provided by Statistics Canada for the province over the years 1981-2009. These were averages of monthly temperature and precipitation used to calculate seasonal temperatures.

Chapter 6: Results

The regression presented in Table 6.1 deals with a sample of dryland farms, as there is less than 1percent of irrigation on farmland in Nova Scotia.

Table 6.1 Nova Scotia Farmland Value Regression

Independent Variable	**Nova Scotia 1981-2009**	**Standard Error**
January Temperature	-8.86	11.05
April Temperature	23.48	20.51
July Temperature	17.38	22.78
October Temperature	-0.63	17.39
January Precipitation	-0.48	0.96
April Precipitation	-0.02	0.67
July Precipitation	0.61	0.77
October Precipitation	-0.49	0.43
Income	0.07	0.01*
Population Density	299.77	73.67*
Population Change %	-14396.41	9881.53
Constant	-6743.14	1558.64*
R^2	0.94	

*# of observations = 29, * indicates significant at 5%.*

Many of the coefficients produced regressing farmland value on climate variables, income, and population variables are insignificant. This is to be expected as the work completed in this paper is based on Mendelsohn's and Reinsborough's (2007) research for the US and Canada, and the results presented in Table 6.1 are similar to those of Mendelsohn's and Reinsborough's (2007) for dryland farms.

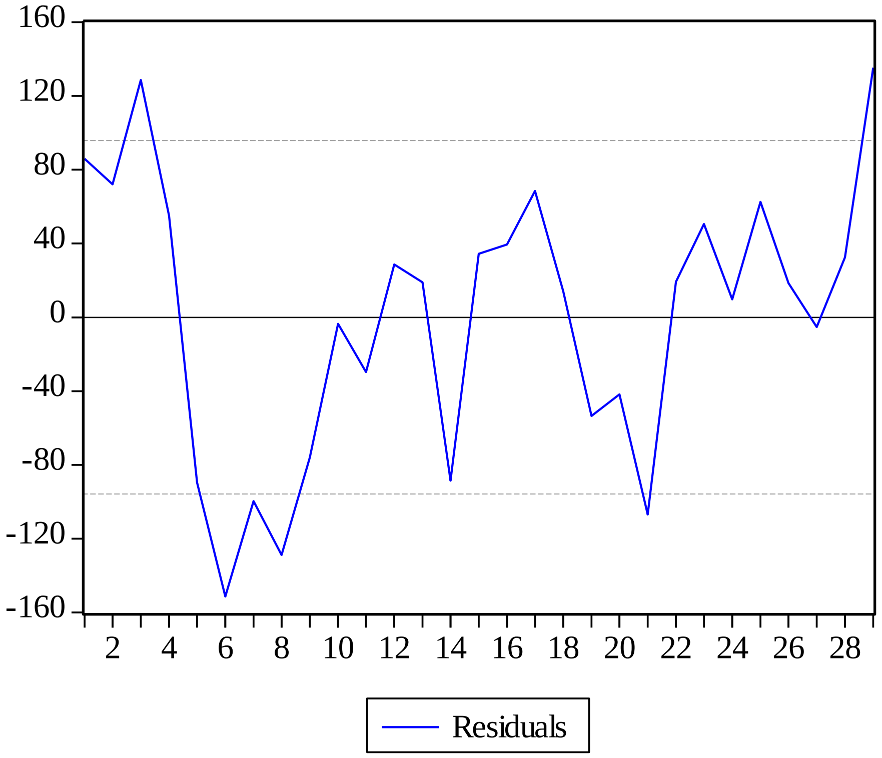
All coefficients except income, population density, and the constant are insignificant. The signs of the coefficients that can be predicted with economic theory are income and population change. According to the results of the work completed by Mendelsohn and Dinar (2009), positive effects from income and population change are expected. Farmland value per acre is expected to increase as income increases and population grows which is in accordance with the coefficients from Table 6.1.

These results suggest that there is no climate response of farmland value in Nova Scotia to changing climate variables of temperature and precipitation but the results also suggest something else.

Because we are dealing with a time series regression where the dependent variable of farmland value could depend on previous values of farmland value and we are omitting relevant soil variables that effect how crops and livestock produce in response to climate, it is possible that the regression is suffering from the phenomenon of autocorrelation. Autocorrelation can be defined as the correlation between members of series of observations observed in time or space (Kendall & Buckland, 1971).

There are several ways to detect for autocorrelation. One way for detection is a visual examination of the residuals across time.

Figure 6.1 Plot of Residuals Across Time



The plot of residuals in Figure 6.1 exhibits a pattern, suggesting that the residuals may not be random. The residuals appear to be increasing over time suggesting some degree of a relationship among them.

Another way to detect for autocorrelation is to run a formal autocorrelation test, known as the Durban-Watson d Test. The null hypothesis for the Durban-Watson d Test is the correlation coefficient of the error terms being equal to zero and the alternative hypothesis is the correlation coefficient of the error terms not being equal to zero. To first run this test, the critical Durban-Watson d statistics have to be obtained from Durban-Watson d statistic tables. With k(the number of coefficients) equal to 12 and an assumed

5 percent level of significance, the upper critical Durban-Watson d statistic is equal to 2.634 and the lower critical statistic is equal to 0.544. From the regression ran to obtain the values in Table 6.1, the Durban-Watson d test statistic is equal to 0.808. According to the Durban-Watson d test decision rule no negative correlation when the test statistic falls between positive 4, and 4 minus the lower critical statistic, the test statistic falls in the rejection region. Therefore, the null hypothesis of no correlation (negative according to the decision rule) is rejected at the 5 percent level of significance and it can be concluded that there is negative correlation among the error terms.

Due to the visual examination showing a pattern and the Durban-Watson d test concluding correlation among the residuals, autocorrelation is present in the model and another regression must be run correcting for this phenomenon.

Table 6.2 Nova Scotia Farmland Value Regression Corrected for Autocorrelation

Independent Variable	**Nova Scotia 1981-2009**	**Standard Error**
January Temperature	-8.86	9.72
April Temperature	23.48	19.59
July Temperature	17.38	16.48
October Temperature	-0.63	15.02
January Precipitation	-0.48	0.61
April Precipitation	-0.02	0.49
July Precipitation	0.61	0.54
October Precipitation	-0.49	0.40
Income	0.07	0.01*
Population Density	299.77	82.52*
Population Change %	-14396.41	8095.84**
Constant	-6743.14	1747.98*
R^2	0.94	

*# of observations = 29, * indicates significant at 5%. **indicate significant at 10%.*

Correcting for the autocorrelation of the regression presented in Table 6.1 by specifying the correction, in the data program (EViews) used, provides the regression presented in Table 6.2. The standard errors of the coefficients from Table 6.1 have been reduced and the coefficient for population change is now significant and at the 10 percent level of significance.

Chapter 7: Conclusion

This paper was intended to infer about the relationship between agriculture and climate change through examining the effects of changing climate variables on farmland value. The value of the dryland farms in Nova Scotia was regressed on climate variables and other exogenous variables to find that a problem of autocorrelation existed. The problem was corrected with a new regression being estimated.

The climate variables of temperature and precipitation were concluded to have no effect on the farmland value of the dryland farms in Nova Scotia as the coefficients of temperature and precipitation were found to be insignificant. These results mirror the results observed by Mendelsohn and Reinsborough in the study on Canadian dryland farms in 2007.

Similar limitations to those of Mendelsohn and Reinsborough (2007) were faced by the regression presented in this paper. The first limitation being the lack of soil data available preventing the inclusion of relevant soil variables in the model. Repeated calls to information officers at Agriculture and Agri-Food Canada, AgraPoint, Nova Scotia Agricultural College and the Nova Scotia Department of Agriculture failed to produce soils data for the province of Nova Scotia as it was said to be not available or nonexistent. Without the inclusion of soils data and thus soils variables in the model, there is a specification error with the model which could possibly pose problems with the results and coefficients. Omitting relevant variables, soils variables in this case, from the model of estimating farmland value could create the possibility of having biased coefficients, biased disturbance variance, biased coefficient variance estimators, and unreliable confidence intervals and hypothesis tests.

Another limitation or concern faced is with the usage of market value per acre of farmland (market value of land and buildings) as a proxy for the net productivity of farmland. I am speculating that the market value per acre is not an efficient proxy for the net productivity of farmland because there does not seem to be a strong theoretical relationship between the market value of land and buildings to climate variables.

Both of the limitations mentioned are possible further research opportunities beyond this paper. Once soils data has been observed and recorded, the model used in this paper can be modified for the inclusion of soils variables. Further research can be done for possible variables that would serve as a better proxy for agricultural productivity and that is thought theoretically to have a strong relationship with changing climate variables. Another possible future extension of this paper could be an examination of the types of crops and livestock grown in Nova Scotia and whether those types are sensitive to changes in water and temperature. If the type of crops and livestock in Nova Scotia are insensitive to changes in water and temperature, this could serve as a reason for the results in the model in this paper concluding that changing climate variables have no effect on agriculture.

References

Agriculture and Agri-food Canada. (2008, March 17) *The Agriculture and Agri-Food System and the Canadian Economy: GDP and Employment*. Retrieved from http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1205769582306&lang=eng#altformat

Canada. Environment Canada. (2010). *National Climate Data and Information Archive: Station Results.* Retrieved March 1, 2011, from http://climate.weatheroffice.gc.ca/advanceSearch/searchHistoricDataStations_e.html?searchType=stnProv&timeframe=3&lstProvince=NS++&optLimit=yearRange&StartYear=1840&EndYear=2011&Month=3&Day=16&Year=2011&selRowPerPage=25&cmdProvSubmit=Search

Canada. Government of Canada. (2010). *Canada's Action on Climate Change: Information on Climate Change.* Retrieved March 1, 2011, from <http://www.climatechange.gc.ca/default.asp?lang=En&n=F2DB1FBE-1>

Canada. Natural Resources Canada. (2004). *Climate Change Impacts and Adaptation: A Canadian Perspective.* Retrieved September 3, 2010, from <http://adaptation.nrcan.gc.ca/perspective/agri_1_e.php>

Canada. Nova Scotia Department of Environment. (2009). *Toward a greener future: Nova Scotia's climate change action plan.* Retrieved February 16, 2011, from <http://climatechange.gov.ns.ca/doc/ccap.pdf>

Canada. Statistics Canada. (2010). *Net farm income: Agriculture economic statistics.* Retrieved January 19, 2011, from < http://www.statcan.gc.ca/pub/21-010-x/21-010-x2010002-eng.pdf>

Dinar, A. & Mendelsohn, R. (2009). *Climate change and agriculture: An economic analysis of global impacts, adaptation and distributional effects.* Northampton, MA: Edward Elgar Publishing, Inc.

Kendall, M.G. & Buckland, W.R. (1971). *A dictionary of statistical terms.* New York City, NY: Hafner Publishing Company.

Mendelsohn et al. (1994). The Impact of Global Warming on Agriculture: A Ricardian Analysis. *The American Economic Review* 84(4), 753-771. Retrieved February 1, 2011, from JSTOR

Mendelsohn, R. & Reinsborough, M. (2007). A ricardian analysis of US and Canadian farmland. *The American Economic Review* 81(1), 9-17. Retrieved January 17, 2011, from SpringerLink

Morison, J.I.L. (1996). Climate change and crop growth. *Environmental Management and Health*, 7(2), 24-27.

Nova Scotia Federation of Agriculture. (2009, May 20). *Agriculture is the key for Nova Scotia's economic sustainability and growth.* Retrieved from http://www.nsfa-fane.ca/media-release-agriculture-key

Oxford Dictionaries. (2010). *Climate change*. Oxford University Press. Retrieved from http://oxforddictionaries.com/view/entry/m_en_gb0993651#m_en_gb0993651

Statistics Canada. (2006). *Agriculture overview, Canada and the provinces - Total farm area, Tenure of land reported as owned, leased, rented, crop-shared or used through other arrangements and Tenure of land used by others* (table). Retrieved from http://www.statcan.gc.ca/pub/95-629-x/1/4123823-eng.htm#12

Statistics Canada. (2005). *Agriculture overview, Canada and the provinces - Total irrigation use for calendar year prior to the census, 2005 and 2000* (table). Retrieved from http://www.statcan.gc.ca/pub/95-629-x/1/4182376-eng.htm

Statistics Canada. (n.d.). Table 051-0001 *Estimates of population, by age group and sex for July 1, Canada, provinces and territories, annual (persons unless otherwise noted)* (table). CANSIM (database). Using E-STAT (distributor). Retrieved from http://estat.statcan.gc.ca/cgi-win/CNSMCGI.EXE