The Impact of Climate Change and Drought Persistence on Farmland Values in New Zealand:

An Application of a Hedonic Method of Climate-Land Pricing

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Summary

We quantify the impacts climate change on New Zealand's agriculture. We implement the Ricardian approach of land climate-pricing using QV data. We explore the nonlinear relationship between climate variables and farmland values while controlling for socio-economic and topographical-geographical features. Furthermore, we measure the persistence of drought using autoregressive (AR) model. We simulate future farmland values under climate change. Preliminary results show the heterogeneity in which rural land values are affected by climate depending on the land use category. The rural land value decreases with summer temperature among all land uses, while it increases with spring temperature. The cumulative impacts of soil moisture deficit in summer reduce farmland values.

Keyword

Land values; agriculture; climate change; drought persistence; New Zealand

Introduction

The increasing trend of global warming has triggered many changes to the Earth's climate. Climate change -as the biggest environmental challenge- is becoming an imminent threat for the future of the world economies particularly for the countries that are greatly dependent on the agricultural sector like New Zealand. Agriculture is perhaps the most sensitive and vulnerable sector to climate change due to its high dependence on climate and weather conditions. There is a generally held belief among experts that changes in temperature and precipitation can cause changes in land and water regimes which in turn affect agricultural productivity (World Bank, 2003) and might lead to higher and more unstable prices (FAO/OECD 2010).

New Zealand's economy relies heavily on its natural environment which agriculture and forestry sectors make a significant contribution to export earnings (more than half of New Zealand's total export income). A sizeable proportion of the total land in New Zealand is used for primary production (agriculture, forestry, and horticulture) (StatsNZ, 2018). The productivity of a parcel of land is reflected in land values, which can differ from parcel to another, depending on the climate factors, soil type, fertility, availability of groundwater for irrigation (Tewari et al., 2013). New Zealand's agricultural land is considered as one of the highest lands valued across the world due to its significant contributors such as appropriate temperate, moist climate and soil which directly influence the agricultural productivity.

On the other hand, the availability of cheap credit together with an increased demand for agricultural commodities led to a bubble in farmland values in New Zealand (Hargreaves and McCarthy, 2010). According the Real Estate Institute of New Zealand (REINZ), during a 15-year period from 2010 to 2015, farmland values have risen by an average of 13.5 percent. The median price per hectare for dairy farms was $37,761, grazing ($15,226), and horticulture ($240,000) (REINZ, 2015). In 2014, alone prices have soared 24 percent. This very rapid increase in the value of farmland have mainly reflected demand for dairy property. Apart from that, the urban market can also influence the rural market. The demand for lifestyle properties within commuting distance of towns and cities are surging throughout New Zealand which results in either farmers selling their farms to another farmer or subdividing and selling lifestyle blocks.

However, land assets in New Zealand are at substantial risks arising from climate change impacts. New Zealand regional climate models project temperature increases everywhere, and greater increases in the North Island than the South, with the greatest warming in the northeast by the end of the 21st century. Regarding precipitation, it varies around the country, increases in the South and West, and decreases in the North and East (MfE, 2018). Accordingly, any climatic change or abnormality, such as drought, strongly affects the agricultural productivity and then land values in different regions of New Zealand.

Despite the importance of this issue, little work has been done on the impact of climate change on farmland values in New Zealand (Allan & Kerr, 2016). The general objective of this research is to explore the impact of climate change on agricultural land prices under different land uses in New Zealand over a study period of 1993-2018, by applying the Ricardian approach of land-climate pricing. The specific objectives of this work are to (1) to measure the day-to-day of the persistence of drought events; (2) to quantify the impacts of climate change and drought persistence (cumulative impacts) on farmland values; and (3) to calculate the future impacts of climate change on farmland values. We also apply Ricardian estimates for various subsamples (dairy farms versus sheep/beef farms and not-irrigated versus irrigated farms) to identify how different parts of New Zealand's agricultural sector response to climate.

Preliminary results show the heterogeneity in which rural land values are affected by climate depending on the land use category. Land values for dairy farming are positively associated with summer and winter climate. Sheep and beef land values are positively associated with spring and winter climate. As for the non-linear relationships captured by the quadratic form of all climate variables we see that value of land decreases with summer temperature among all land uses while increase with spring temperature.

This paper is structured as followed; section 2 provides an overview of the literature on analysing the risk from climate change on agriculture to identify the gap in the research that we aim to fill. The following sections present data sources, the empirical model used, and a spatial description of the data. The main findings are summarised in section 6, and the last section concludes. The current manuscript is still under development and the results presented constitute preliminary outcomes. Further results and their scrutiny are work in progress and shall be provided in a later version of this manuscript.

Literature Review

Numerous studies have evaluated the major impacts of climate change on agriculture, with a special focus on countries that are highly dependent on the agricultural sector (Fuhrer et al., 2006; Kumar et al., 2011; P. Birthal et al., 2014; Howitt et al., 2014; Ali et al., 2017). These studies have estimated the economic impact of climate change using empirical or experimental production functions to calculate environmental damage. However, Mendelson et al. (1994) have opined that there is a bias in the production function approach as it tends to overestimate the damages that arise from climate variables; this is because the production function omits a range of adaptation strategies to climate and environmental changes adopted by the farmers. Mendelson et al developed a new technique called Ricardian approach, in which, instead of analysing the yields of specific agricultural products, the sensitivity of net farm profits or land values to climate, geographic, economic and demographic factors are measured (Mendelson et al., 1994). The Ricardian approach is a hedonic method of farmland pricing that assumes that the value of a land parcel equals the present value of future rents or profits generated through all activities on the farm (Schlenker, et al. 2006). Theoretically, this approach assumes that farmland values reflect farm productivity and its potential profitability in the long run, "implying spatial variations in climate drive spatial variations in land uses and in turn land values" (Polsky, 2004). Notably, since climate is considered as an exogenous factor in the land-climate Ricardian method, the economic impacts of climate changes can be effectively captured by variations in farmland values across diverse conditions. More importantly, this technique explicitly incorporates farmer adaptation by using cross-sectional variation.

On the other hand, as for any conceptual method, Ricardian analysis confronts a number of limitations. First, Ricardian model does not consider the transition cost thus resulting in underestimating of climate change costs (Kelly et al., 2005). Another shortcoming of the Ricardian approach is the assumption of constant prices, which could lead to some bias (Quiggin & Horowitz, 1999). However, given an increasing in crop production in some regions of the world and the reductions in others due to climate change effects, international crop will remain unchanged at the global level, and therefore the changes in the crop prices is considered to be relatively small (Reilly et al., 1994). Finally, it reflects current technology and current agricultural policies. In spite of these limitations, the Ricardian technique has been proved as a practical tool for estimating the effects of global climate change on agricultural land values. The following section of this literature review highlights some important studies that developed the Ricardian approach and also attempted to address the drawbacks of the original.

Extensive literature has focused on estimating the impacts of climate change on agricultural land values by applying the Ricardian approach across various countries including the United States (Mendelsohn and Nordhaus, 1999; Mendelsohn, 2001; Seo and Mendelson; 2008; Quaye et al., 2018), Canada (Reinsborough, 2003), Europe (Moore and Lobell, 2014; Vanschoenwinkel et al., 2016; Van Passel et al., 2017), South Africa (Gbetibouo, & Hassan, 2005) Sri Lanka (Seo et al., 2005), Pakistan (Hussain and Mustafa, 2016). They have established that there is a nonlinear relationship between farmland values and temperature and precipitation. Mendelsohn & Massetti (2017) summarized that the estimates of Ricardian model show that net farm revenue falls by 8–12% under global average temperature increases of 2◦C and precipitation increases of 7%. The Ricardian approach has also established that impacts of climate change differ by region. Agricultural area in warm regions is likely to be a net loser while those in cold regions may benefit.

In previous Ricardian analysis, the absence of irrigation variables was also criticized, however, some studies have tried to address this issue carefully. Schlenker et al. (2006) examine the impacts of climate change on US farmland values by restricting their analysis to rain-fed regions to avoid the irrigation bias. They concluded that once irrigation is accounted, the results become more robustness across the models. Using a similar method, Schlenker et al. (2005), explored that irrigated and dryland counties cannot be pooled in a single regression equation. The value of agricultural land in irrigated areas have been found to be less sensitive to changes in precipitation (Mendelsohn & Dinar, 2003). Seo et al. (2008) assessed the impact of climate change on 2300 farms in South American considering farmer adaptations and testing several econometric specifications. They found that farmland values reduce with increase in both temperature and precipitation exception of irrigated lands. Small farms were also realised more vulnerable to climate change.

Most primary Ricardian studies relied on a single-year or repeated cross-sectional analyses, however, an econometric work on American agriculture has put the question of whether Ricardian function stable over time. Massetti & Mendelsohn (2011) argued that researchers are not able to separate short-term (e.g. weather and price shocks) from long-term events such as climate by relying on one single year. They also debated that repeated cross-sectional analyses are weakly specified intertemporal models. In their study, they relied on panel data techniques to investigate the effect of climate on agriculture in 48 states over the US. They established that the panel models are more likely to be appropriately specified and the estimates of climate are consistent across years from panel methods. Following Massetti & Mendelsohn (2011), which provide evidence of an interesting evolution of Ricardian application to panel data, a number of studies have carried out a Ricardian panel data analysis to estimate the impacts of climate on agricultural outcomes (Tewari et al., 2013; Chatzopoulos & Lippert, 2016; Bozzola et al., 2017; Carter et al., 2018). These studies have applied the Ricardian method at different levels i.e. aggregated or individual data. However, studies have revealed that a strong aggregation bias when the analysis is implemented in an aggregated fashion instead of on individual data due to the limited regional representativeness of climate, socioeconomic, soil, geographic and topographic data. (De Salvo et al., 2013).

Literature had made substantial progress in measuring the impact of climate change on land values; however, little study has been done to directly measure the cumulative impact of weather events occurring over multi days such as heat waves or droughts and then analysis the cumulative impact of droughts on net farms' revenue. Given these gaps in the existing literature, this paper not only values the impact of climate change on rural land values using historical relationships between land values and weather but also develop the latest advances in climate econometrics to flexibly define drought to measure cumulative impacts.

Data

Data on land values come from Quotable Value New Zealand (QVNZ) which provides government valuations on a 3-year cycle for all properties in New Zealand for 1995–2018. The QVNZ data record the total capital value of all assessments, and the total land area assessed by QVNZ for each land use category for each MB. We are interested in the value of rural land, but we focus our analysis on the capital value (land value plus buildings value). Since our focus is on discovering variations in the rural land value, our analysis is based on rural meshblocks only. We focus our analysis on four-main rural land uses: dairy, sheep and beef, horticulture and forestry. Dairy, sheep/beef, and exotic forestry alone account for around 75% of private rural land in New Zealand (Kerr and Olssen 2012). We build an unbalanced panel of MBs that have at least one dairy, sheep/beef, or forestry assessments in each valuation cycle.

To compute the climate variables we use the Virtual Climate Station Network (VCSN) data provided by the National Institute of Water and Atmospheric Research NIWA. The VCSN data is updated daily weather in a regular grid approximately 5 × 5 km covering all of New Zealand (11491 grid points). The VCSN estimates daily minimum and maximum temperature, and soil moisture, among other variables, and spatially interpolates raw station observations across space using a trivariate (elevation, latitude, and longitude) thin plate smoothing spline model. Following Schlenker and Roberts (2009), first we interpolate minimum and maximum temperature in each grid cell in each day using the single sine method. We then compute nonlinear transformations of all variables at the grid-cell-day level before aggregating in order to preserve within-meshblock weather variation. Finally, the spatial averaging for a given day is done using area-overlap weights with the VCSN grid cells. We overlaid the 2006 meshblock boundaries to construct meshblock level seasonal climate variables. The seasonal climate is the arithmetic mean of climate variables in summer (December, January, and February), autumn (March, April, May), winter (June, July, August) and spring (September, November, October) over the 30-year period 1981-2010.

Our control variables including, soil quality indicators, slope, and irrigation data are provided by Land Environments New Zealand (LENZ) database and NZ Landcare Research (see Appendix 1). We also use the median house price at meshblock to control for local land markets. This is a proxy for the opportunity cost of keeping land in farms (Massti and Mendelson, 2011). For flood- prone variable, we use the flood hazard map for (LENZ) to calculate the percentage of land that is prone to flooding.

Methodology

The Ricardian approach, assuming land rents reflect the expected agricultural productivity, was developed to examine the long-run effects of climate change on agriculture, given likely climate adaptation by farmers (Mendelson et al., 1994). This technique estimates how much of the observed cross-sectional variation of land values (or net revenue) can be explained by climate and additional explanatory variables. The Ricardian method is a cross-sectional model but we use panel data to regress land values against vectors of climate variables and other controls following Massetti and Mendolsohn (2011). One of the advantages of estimating the model with a panel data is that we can easily separate annual events (such as weather and price shocks) from long term events (e.g. climate) (Massetti and Mendolsohn, 2011).

We also apply Ricardian estimates for various subsamples to identify how different parts of New Zealand's agricultural sector response to climate. These evaluations provide more understanding of how New Zealand farms have been affected by climatic conditions.

The Ricardian method assume s the value of farmland (V) of each farm i equals the present value of rent revenue from farm-related activities:

$$V = \int_t^{\infty} [\sum PQ(I, C, X, Z) - \acute{R}\, I] e^{-\delta t} dt \qquad (1)$$

Where P is the market price of output, Q is output, I is a vector of purchased inputs (other than land), C is a vector of climate variables, X is a vector of time-varying variables, Z is a vector of time-invariant control variables (such as soil and geographic factors), R is a vector of input prices, t is time and δ is the discount rate. Farmers are assumed to maximize the land value (net revenue) by choosing I given climate, soil, geographic variables, market prices, and other socio-economic conditions.

Since literature suggests that there is a non-linear relationship between land values and climate variables (Mendelson et al., 1994; Seo and Mendelson, 2008; Hussain and Mustafa, (2016)), the general model of quadratic follows the form:

$$V_{it} = \alpha_{it} w_{it} + \beta_{it} w_{it}^2 + c\boldsymbol{Z}_i + \gamma_t + \mu r + \varepsilon_{it} \qquad (2)$$

Where LVit is the rural land value per hectare, w_it represents the vector of climate variables (30-year average of temperature and soil moisture), potentially computed separately for different seasons of the year, while w_{it}^2 is the quadratic form of the vector of climate variables. One of the criticisms of Ricardian approach is omitted variable bias. To minimize this problem we use a rich dataset of geographic, socioeconomics variables to include into the model. So Zi is a set of control variables that explain variation in land values independently of climate (such as distance from town/port, soil quality, slope, flood-prone area, water deficit, house price), and μ_r and γ_t are regional and time fixed effects. We include regional fixed effect to capture regional exogenous variables such as regional agricultural polies and other characteristics that are not observed. We use log-linear functional form as is standard in the Ricardian studies (Mendelson et al., 1994; Mendelsohn & Dinar, 2003, Seo and Mendelson, 2008) and also due to large variation in the values of rural land in New Zealand which explained by locational features and productivity.

It is likely that the climate, and soil and other geographic or socioeconomics variables are spatially correlated as their unmeasured characteristics usually display a geographic pattern (Massetti and Mendolsohn, 2011). Thereby, OLS estimates of standard errors will be biased downwards in the presence of spatial autocorrelation. As a partial correction for this, we cluster the standard errors in all specifications at the district level. This assumes that the autocorrelation in these variables occurs within each district, and that observations are independent across districts.

Specifying drought in Ricardian analyses of climate change

Traditional climate change valuation studies that use the Ricardian approach typically model climate using quadratics in temperature and precipitation, with some studies also including other variables and nonlinear transformations.

However, no prior study specifies its model such that the typical daily temporal sequence of weather through the year plays any part in explaining variation in land values. For example, a place that tends to experience adverse weather over several sequential days (i.e. concentrated in time) is treated the same as a place that experiences the same weather over days that are spread out in time.

Importantly, this limitation of the previous literature has prevented it from modelling a common feature we associate with drought, that drought occurs over multiple sequential days, weeks, or months.

As a key scientific contribution of this study, we introduce the typical temporal sequence of weather into Ricardian analysis. We incorporate autoregressive (AR) coefficients to measure the importance of the day-to-day weather persistence into two terms of equation (2) by leveraging of the time series data:

$$V_i = \alpha + \beta_1 T_i + \beta_2 T_i^2 + \beta_{1\rho}\rho_{Ti} T_i + \beta_3 SM_i + \beta_4 SM_i^2 + \beta_{3\rho}\, \rho_{SMi} SM_i + \boldsymbol{\gamma}'\boldsymbol{Z} + \varepsilon_i \quad (3)$$

Where ρ_{Xi} is the AR(1) coefficient calculated using daily data for variable X and location i. That is, ρ_{Xi} comes from the following OLS regression:

$$X_{it} = \alpha + \rho_{Xi} X_{i,t-1} + \nu_{it} \quad (4)$$

This will be the AR term associated with each weather repressor computed using the daily time series of weather, computed over 30 years. The use of AR coefficients to measure the consecutive nature of the drought is attractive as AR coefficients are unit-free, providing a measure of day-to-day persistence that does not require further standardization to be comparable across variables and time periods. The AR coefficients will then be a measure of how persistence of weather impacts the marginal effect of a change in temperature.

Prediction of Climate Change Impacts

We then follow the climate econometrics literature and use the output from the simulations of climate-change scenarios to calculate the impact of climate change on land values for all locations in Austria. The change in land value, ΔV, resulting from a climate change C0 to C1 can be measured as follows (Seo and Mendelson, 2008):

$$\Delta V_i = V_{land}(C_1) - V_{land}(C_0) \quad (4)$$

The predicted effect of climate change on agricultural land values is measured as the difference between predicted farmland value under new climate and the value of land under the current climate.

Results and Discussion

Table 1 indicates summary statistics for our dependent and independent variables during 1993-2012, separately for New Zealand and each island. The highest average land value for the period 1993-2012 is observed in the North Island. This figure is followed by the national average figure of 9827 NZD and the South Island reaching a 5101 NZD. As for the climatic values, we find that average temperature for the North Island is higher than the temperature of the South Island for all the seasons of the year, indicating warmer conditions in the North Island. Regarding the areas prone to inundation and the location of rural land, the data shows a 21% of all New Zealand rural land located in areas with some level of flood risk that is from slight to very severe flood risk. The national value is approximately the same for the North and South Islands.

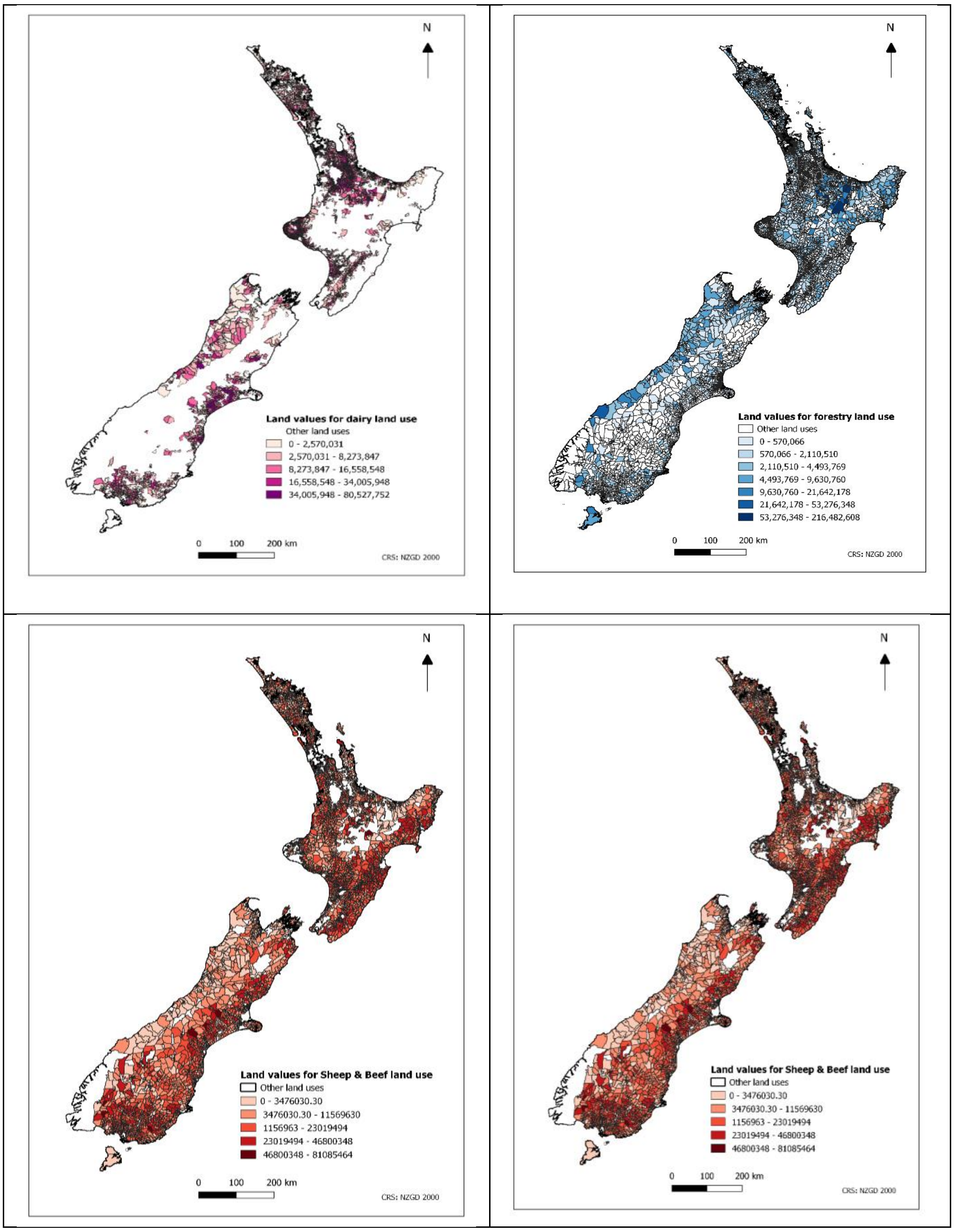
As for the topography, approximately 44% of New Zealand's rural land are located in areas of defined as low slope areas, with gradients ranging from 1 to 10 per cent change. This figure is similar when comparing it to the north island's proportion of rural land (51%) located in low slope. In contrast, the South Island has the highest proportion (~8%) of rural land located on steep land i.e. land with gradients above 20 percent change. More irrigated land are located in the South Island which is in the Canterbury region. House prices are higher on average in the North Island.

Figure 1 shows the spatial distribution of average land values over the period 1995-2012 for different land uses- dairy, sheep/beef, forestry and horticulture- at meshblock level. Land values tend to be higher in the North Island for all land uses except horticulture. Dairy and sheep/beef land values are higher in the Waikato, Bay of Plenty, Taranaki, Canterbury, and Southland. Land values for horticulture land use is more valuable in Marlborough region in the South Island. There is also a slight east-west gradient, particularly in the South Island, where the east coast tends to be warmer than the west. Soil moisture shows a much stronger east-west gradient in the South Island. The West Coast of the South Island is well known for being the wettest region in New Zealand.

Table 1. Summary Statistics, 1993-2012

	New Zealand		North Island		South Island	
Dependent variables	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
Land value per hectare	9827.471	798000	7329.586	13758.79	5101.75	12927.96
house price mb	134000	52027.47	148000	98877.71	4793.85	11379.27
fraction land irrigated	.037	.122	.013	.07	0.081	0.174
climate variables						
spring Temp	12.589	1.554	13.211	1.134	10.936	1.288
summer Temp	17.275	1.635	17.945	1.106	15.494	1.472
autumn Temp	13.789	1.977	14.666	1.357	11.457	1.383
winter Temp	8.967	2.109	9.936	1.384	6.39	1.427
spring SoilM	-32.138	17.085	-26.993	10.996	-45.82	22.114
summer SoilM	-88.198	21.706	-85.371	16.3	-95.716	30.658
autumn SoilM	-61.636	21.287	-57.923	14.301	-71.512	31.307
winter SoilM	-5.391	11.012	-1.053	4.002	-16.927	14.768

Figure 1. Spatial distribution of average land values by land use, 1993-2012



We estimate the Ricardian regression model (2) to analyse the relationship between land values and some climate and non-climate variables for each land use type. Various specifications are considered for the estimation of farmland values using pooled OLS and fixed effects models (FE) in our study. The first specification only includes climate variables (temperature and soil moisture) for different seasons of the year in order to show the significance of the non-farm factors in the model. For each climate variable, we include linear and quadratic terms to reflect the nonlinearities that have been observed from previous field studies. The linear form reflects the marginal impact of climate change on land values, while the quadratic terms represent how land values differ compared to the mean. In other words, how much the values of land respond to severity of climate. The signs of the quadratic terms of the coefficients illustrate the U-shape or hill-shape of the relationship. The negative (positive) sign corroborates a hill shaped (∩) (U-shape) relationship between land values and climatic variables, respectively. We also include soil characteristics, other environmental and socioeconomic variables to control for exogenous factors influencing farmland values. We also control for unobserved temporal and spatial effects using year and regional fixed effects.

We are interested in seasonal differences because climate change is going to shift seasonal temperature variations. Since it is difficult to interpret the effects of changes in climate coefficients from the quadratic forms, we calculate the seasonal marginal impacts at the mean level by land use and plot them out. Figures 1-8 represent the nonlinear relationship between temperature and changes in land values for each land use category. These graphs show the effect of seasonal temperature on dairy land values. The vertical red dashed-line is the average temperature for land use. While the vertical dotted-line is the average temperature for all land uses. The blue line shows the nonlinear estimates of seasonal temperature effects and 95% confidence intervals in dashed lines The vertical axis displays the log of land values (per hectare) and horizontal axis is histogram of average temperature across all rural meshblocks. When we compare two points on the any plot, a vertical difference of 1 shows approximately 100% difference in average rural land value. For example, for dairy farming, moving from the mean spring temperature (13°C) to 14 °C, results in a predicated land value decline of about 300%, holding other things constant.

The results show that the overall impact of climate measured by the marginal effects and climatic seasons is largely different across the various land uses and climatic seasons. The spring and winter temperature marginal are positive for dairy land use indicating the benefit of a calving time. However, the autumn temperature marginal are negative. From figure 1 we can see in spring and winter, one degree away above the mean is going to raise land values. The relationship between spring temperature and land values is nonlinear. While in the other seasons are almost linear. When moving away above the mean, it is likely that we see a steeper slope implying a larger effect. When moving away below the mean, we see a flatter curve. Figure 2 shows the effect of seasonal soil moisture on dairy land values. Across seasons we have flat curves, and the effects are quite small and non-statistically significant.

For sheep/beef land use, all the models indicate that higher spring and autumn temperatures are significantly beneficial on land values; but that higher summer and winter temperatures are harmful. As for forestry, the relationship between spring temperature and land values in U-shape, and temperature in spring is beneficial. While temperature in other seasons are harmful for forestry land use. Land dedicated to horticulture significantly benefit from spring and winter temperatures and spring soil moisture.

In general, the quadratic terms also show different non-linear relationship across land use categories. The results show that the value of land decrease with summer temperature among all land uses while increase with spring temperature. The response of land value to winter temperatures is hill-shaped for Sheep/beef and forestry land uses. This means that temperature affects the land value positively up to a certain level, above which it reduce the land values.
Several of covariates variables in the regression are also significant. For dairy, higher soil acidity decreases the land values. Silt sand sandy and coarse soils tend to be beneficial. Flat and low slope lands are more valuable for all land uses except forestry which makes sense. Distance to local amenities like airport, cities, schools and ports reduce land value. The coefficient for port is larger than for cities indicating ports cause more valuable markets for farmers.

Figure 2. Nonlinear relationship between temperature and land values for dairy land use

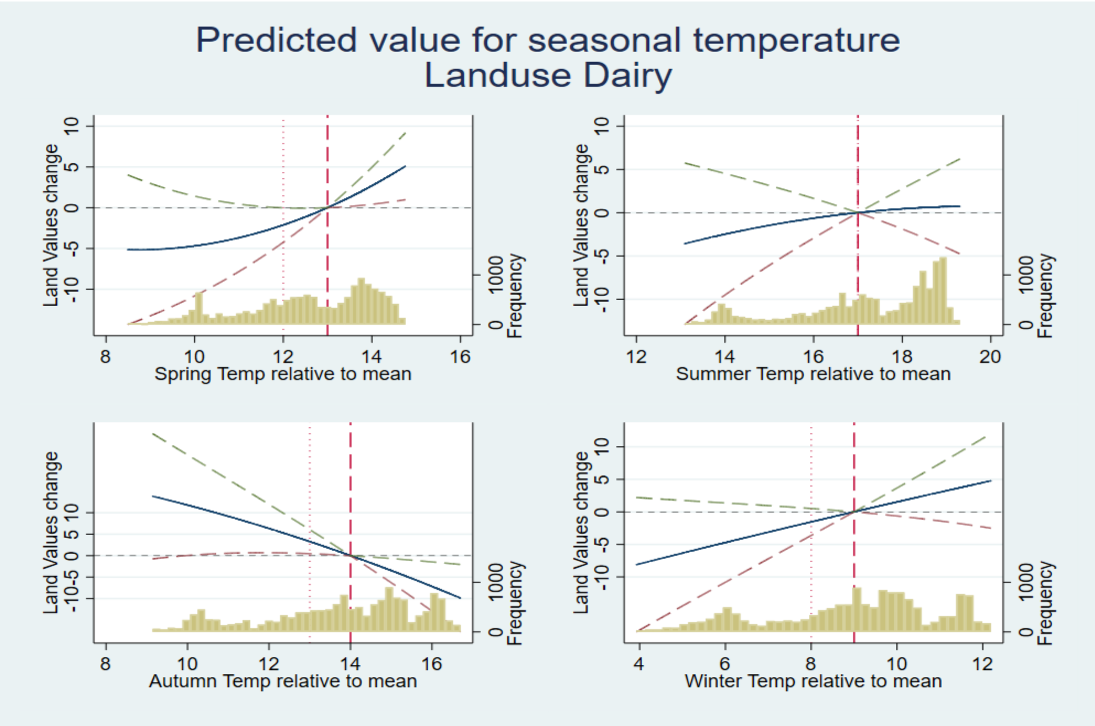


Figure 3. Nonlinear relationship between soil moisture deficit and land values for dairy land use

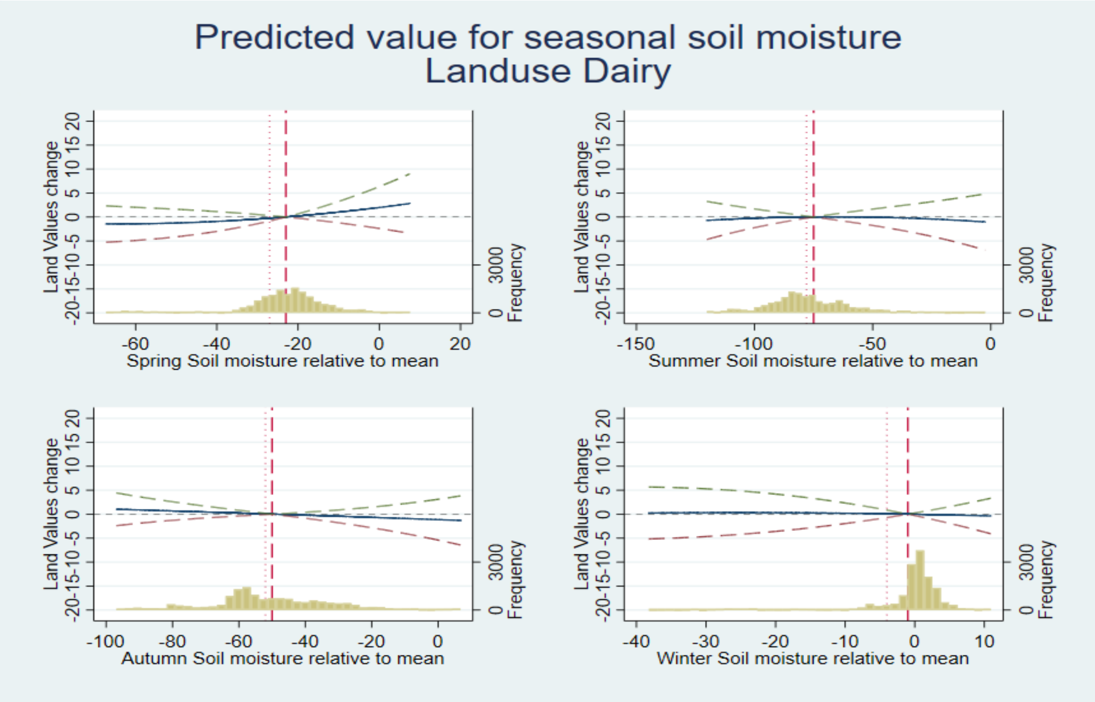


Figure 4. Nonlinear relationship between temperature and land values for sheep/beef land us

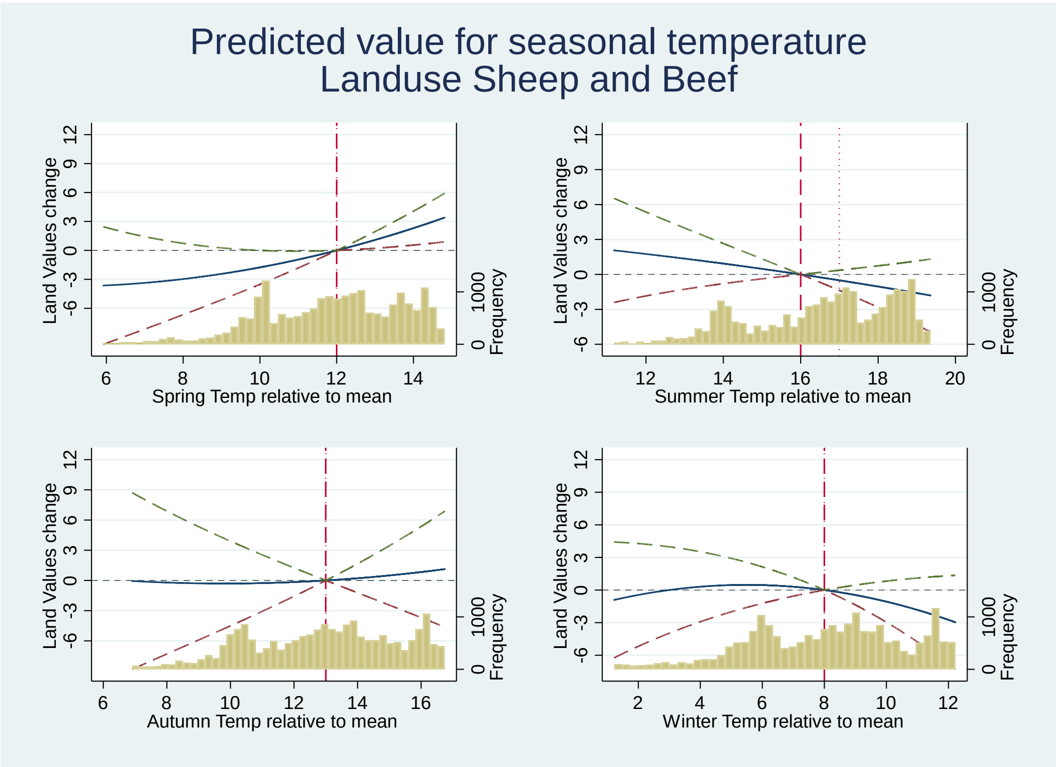


Figure 5. Nonlinear relationship between temperature and land values for forestry land use

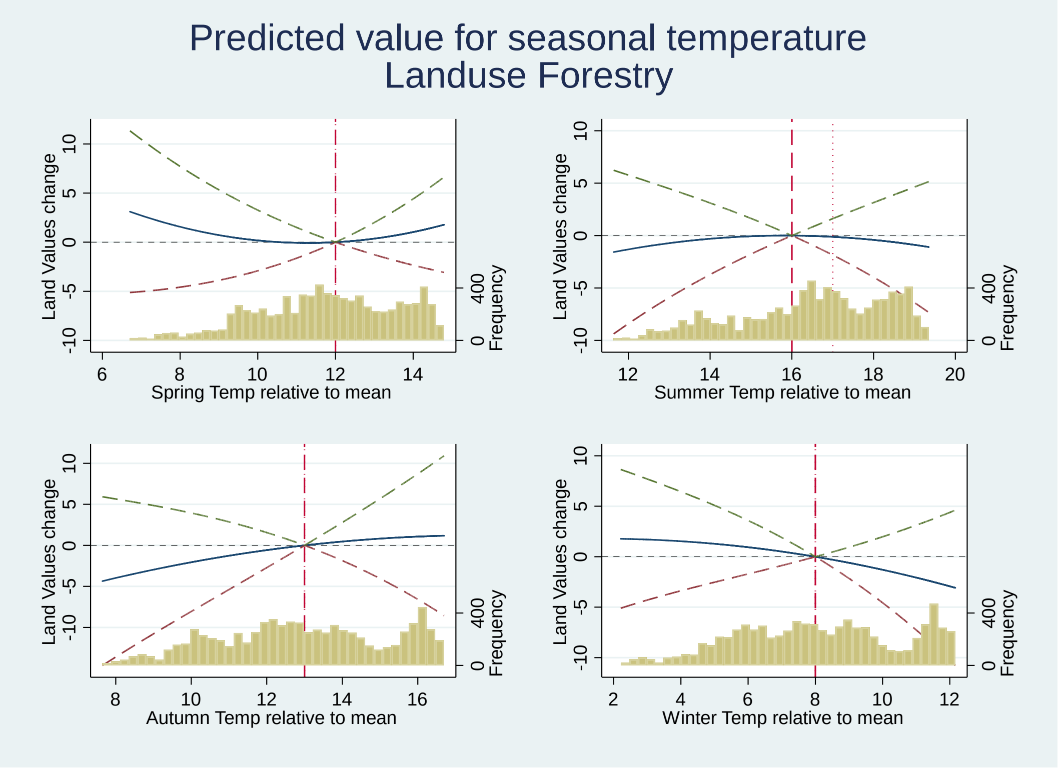


Figure 6. Nonlinear relationship between temperature and land values for horticulture land use

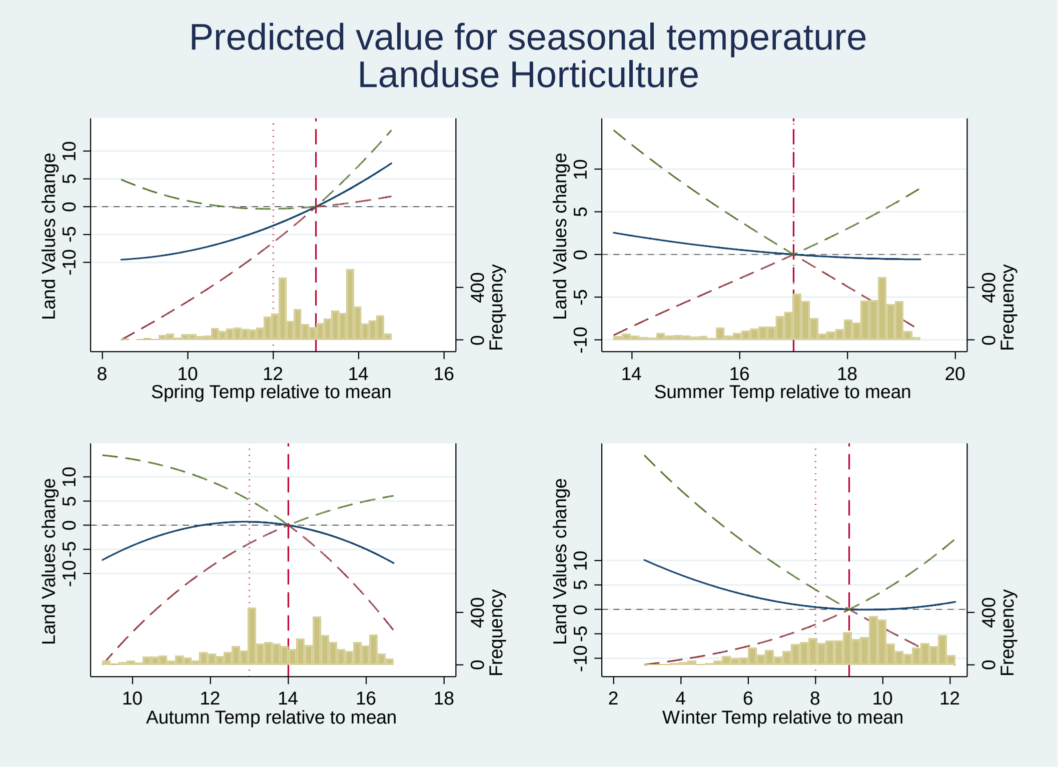


Table 2 represents the results of persistence of drought on land values for dairy land use. The persistence of summer soil moisture deficit is negative and statistically significant, as expected. So increases in the persistence of summer soil moisture deficit are associated with lower land values. The persistence of autumn soil moisture deficit has a positive effect. Perhaps this is because the ups and down are associated with very wet or very dry conditions. However, we associate the summer temperature and soil moisture persistence terms with drought persistence. Maps 2 and 3 map show the spatial distribution of the AR(1) coefficients, which indicates the persistence of temperature and soil moisture deficit across seasons, respectively. For example, in summer North Island indicates a tendency for persistence in temperature than South Island. Also in south island we can see more variations than the North Island. Interesting, according to AR of temperature, east coast of South island is less persistent of temperature is less than west coast while according to soil moisture deficit it more persistent than the west coast. While as with soil moisture, all area in the North Island tends to be much more persistent than south Island.

Table 2. Ricardian Model Estimates for the Persistence of Drought dairy landuse

	Pooled OLS	FE		Pooled_OLS	FE
Spring temp	-5.16*	-5.29*	Autumn SoilM	0.13**	0.04
	(2.68)	(3.12)		(0.06)	(0.06)
Spring Temp sq	0.20*	0.24**	Autumn SoilM sq	0.00	0.00
	(0.12)	(0.11)		(0.00)	(0.00)
Spring Temp AR(1)	1.05	-4.44	Autumn SoilM AR(1)	19.94***	9.83*
	(8.86)	(10.96)		(5.89)	(5.03)
Summer Temp	4.25	1.76	winter SoilM	4.04*	1.76
	(3.98)	(4.31)		(2.30)	(2.36)
Summer Temp sq	-0.06	0.01	winter SoilM sq	-18.23*	-1.39
	(0.13)	(0.12)		(10.02)	(14.91)
Summer Temp AR(1)	-11.58**	0.02	winter SoilM AR(1)	-5.16*	-5.29*
	(5.44)	(8.48)		(2.68)	(3.12)
Autumn Temp	3.53	6.20	_cons	0.20*	0.24**
	(4.87)	(4.37)		(0.12)	(0.11)
Autumn Temp sq	-0.22	-0.31**	Regional FE	No	Yes
	(0.17)	(0.15)	Year FE	No	Yes
Autumn Temp AR(1)	-4.82	-5.32	Obs.	15002	15002
	(6.32)	(10.21)	R-squared	0.28	0.46
winter Temp	0.23	-1.14			
	(2.18)	(1.95)			
winter Temp sq	0.06	0.11			
	(0.11)	(0.08)			
winter Temp AR(1)	9.69	-9.26			
	(6.29)	(8.15)			
Spring SoilM	0.25*	0.06			
	(0.13)	(0.13)			
Spring SoilM sq	0.00	0.00			
	(0.00)	(0.00)			
Spring SoilM AR(1)	2.08	0.96			
	(2.58)	(3.55)			
summer SoilM	-0.18**	-0.08			
	(0.07)	(0.09)			
summer SoilM sq	-0.00**	-0.00			
	(0.00)	(0.00)			
summer SoilM AR(1)	-27.01***	-15.40**			
	(6.22)	(6.47)			

Standard errors are in parenthesis
**** p<0.01, ** p<0.05, * p<0.1*

Figure 7. Spatial distribution of seasonal AR(1)coefficient associate with temperature

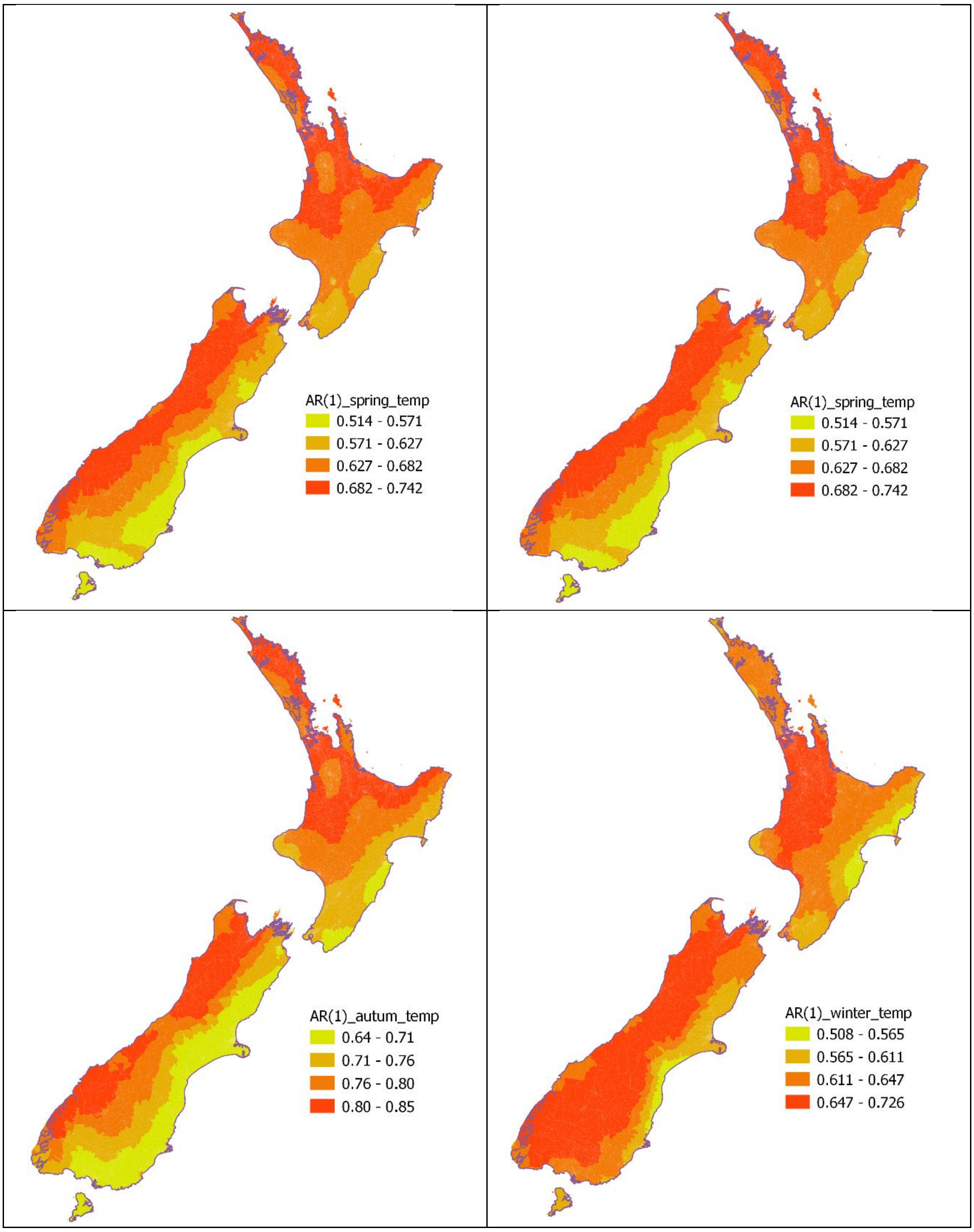
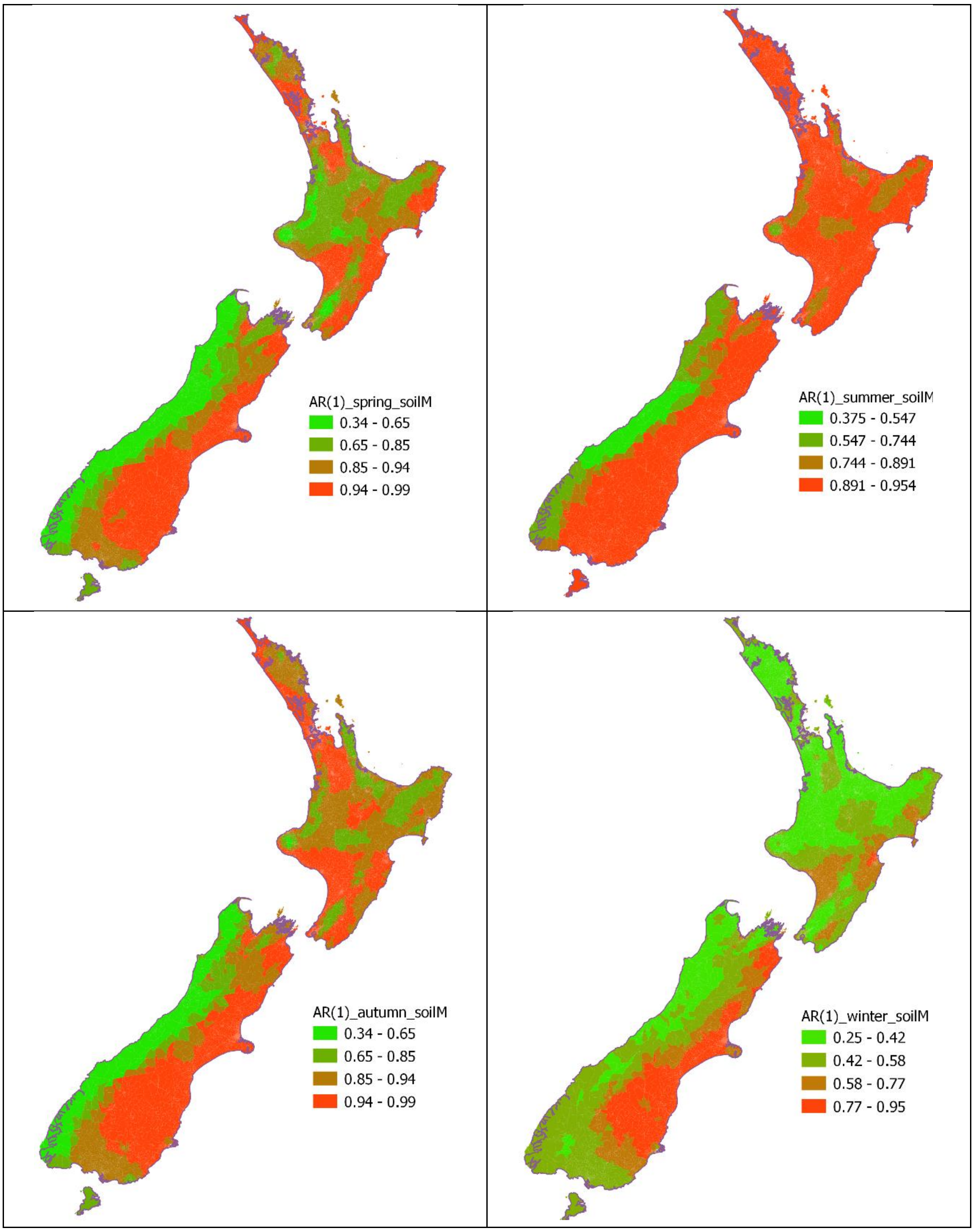


Figure 7. Spatial distribution of seasonal AR(1)coefficient associate with soil moisture deficit



Conclusion

Climate change influences extensively the productivity and the value of a parcel agricultural land. Hence changes in the farmland values are largely imposed by climatic anomalies. Therefore, there is a dire need to address the issue of climate change and its effects on different sectors of the economy particularly the agricultural sector in order to design strategies for policy making. This work evaluates the impact of seasonal climatic and non-climatic variables on New Zealand's agricultural land values using a hedonic method of climate-land pricing during 1993-2012. We estimate the Ricardian approach for different land uses -dairy, sheep/beef, forestry and horticulture- at meshblock level. We also assess how the typical daily temporal sequence of weather plays any rolls in explaining variation in land values. This analysis provides a better understanding of the effects of climate change in New Zealand and inform climate change adaption efforts. Moreover, it shows which agricultural sub-sectors and areas are most at risk from future climate change.

References

Birthal, P., Negi, D. S., Kumar, S., Aggarwal, S., Suresh, A., & Khan, M. T. (2014). How sensitive is Indian Agriculture to Climate Change? Indian Journal of Agricultural Economics, 69(4).

Bozzola, M., Massetti, E., Mendelsohn, R., & Capitanio, F. (2017). A Ricardian analysis of the impact of climate change on Italian agriculture. European Review of Agricultural Economics, 45(1), 57-79.

Carter, C., Cui, X., Ghanem, D., & Mérel, P. J. A. R. o. R. E. (2018). Identifying the Economic Impacts of Climate Change on Agriculture. 10, 361-380.

De Salvo, M., Raffaelli, R., & Moser, R. (2013). The impact of climate change on permanent crops in an Alpine region: A Ricardian analysis. Agricultural Systems, 118, 23-32. doi:https://doi.org/10.1016/j.agsy.2013.02.005

Fuhrer, J., Beniston, M., Fischlin, A., Frei, C., Goyette, S., Jasper, K., & Pfister, C. (2006).

Climate risks and their impact on agriculture and forests in Switzerland Climate Variability, Predictability and Climate Risks (pp. 79-102): Springer.

Gbetibouo, G. A., & Hassan, R. M. (2005). Measuring the economic impact of climate change on major South African field crops: a Ricardian approach. Global and Planetary Change, 47(2), 143-152. doi:https://doi.org/10.1016/j.gloplacha.2004.10.009

Hussain, S.A. and Mustafa, U. (2016). Impact of climate change on agricultural land values: an application of Ricardian model in Punjab Pakistan. Department of Environmental Economics, working paper No.8.

Kelly, D. L., Kolstad, C. D., & Mitchell, G. T. (2005). Adjustment costs from environmental change. *Journal of Environmental Economics and Management, 50*(3), 468-495. doi:https://doi.org/10.1016/j.jeem.2005.02.003

Kerr, S., and Alex Olssen. 2012. "Gradual Land-Use Change in New Zealand: Results from a Dynamic Econometric Model." Motu Working Paper 12–06. Wellington: Motu Economic and Public Policy Research. http://www.motu.org.nz/publications/detail/gradual_land-use_change_in_new_zealand_results_from_a_dynamic_econometric_m.

Kumar, S. N., Aggarwal, P. K., Rani, S., Jain, S., Saxena, R., & Chauhan, N. (2011). Impact of climate change on crop productivity in Western Ghats, coastal and northeastern regions of India. Current Science, 332-341.

Mauser, W. and Ludwig, R. (2002): A research concept to develop integrative techniques, scenarios and strategies regarding Global Changes of the water cycle. In: Beniston, M. (ed.) (2002): Climatic Change: Implications for the hydrological cycle and for water management. - Advances in Global Change Research 10: 171-188.

Mendelsohn, R., Nordhaus, W., and Shaw, D.: 1994, 'the impact of global warming on agriculture:A Ricardian analysis', American Economic Review 84, 753–771.

Mendelsohn, R. and Nordhaus, W. D.: 1999, 'the impact of global warming on agriculture: A Ricardian analysis: Reply', The American Economic Review 89(4), 1049–1052.

Mendelsohn, R, Dinar, A., and Sanghi, A.: 2001, 'The effect of development on the climate sensitivity of agriculture', Environment and Development Economics 6, 85–101.

Mendelsohn, R., & Dinar, A. J. L. e. (2003). Climate, water, and agriculture. *79*(3), 328-341.

Mendelsohn, R. O., Massetti, E. J. R. o. E. E., & Policy. (2017). The use of cross-sectional analysis to measure climate impacts on agriculture: theory and evidence. *11*(2), 280-298.

MfE. (2018). Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition. *Wellington: Ministry for the Environment*.

Polsky, C. (2004) Putting Space and Time in Ricardian Climate Change Impact Studies: Agriculture in the US Great Plains, 1969-1992. Annals of the Association of American Geographers, 94, 549-564. http://dx.doi.org/10.1111/j.1467-8306.2004.00413.x

Reinsborough, M. J. (2003) A Ricardian Model of Climate Change in Canada. Canadian Journal of Economics 36:1, 27–31.

Quaye, F., Nadolnyak, D. and Hartarska, V. (2018). Climate change impacts on farmland values in the Southeast United States.

Quiggin, J., & Horowitz, J. K. (1999). The Impact of Global Warming on Agriculture: A Ricardian Analysis: Comment %J American Economic Review. *89*(4), 1044-1045. doi:10.1257/aer.89.4.1044

Reilly, J., Hohmann, N., & Kane, S. (1994). Climate Change and Agricultural Trade: Who Benefits, Who Loses? *Global Environmental Change, 4*(1), 24-36.

REINZ. (2015). Rural Statistics *The Real Estate Institute of New Zealand (REINZ)*.

SEO, S., Mendelsohn, R., & Munasinghe, M. (2005). Climate change and agriculture in Sri Lanka: A Ricardian valuation. Environment and Development Economics, 10(5), 581-596. doi:10.1017/S1355770X05002044.

Seo, N., & Mendelsohn, R. J. C. J. o. A. R. v. (2008). Analisis Ricardiano del impacto del cambio climatico en predios agricolas en Sudamerica].[A Ricardian analysis of the impact of climate change on South American farms]. *68*(1), 69-79.

Schlenker, W., Hanemann, W. M., & Fisher, A. C. (2006). The Impact of Global Warming on U.S. Agriculture: An Econometric Analysis of Optimal Growing Conditions. 88(1), 113-125. doi:10.1162/rest.2006.88.1.113

Schlenker, W., Hanemann, W. M., & Fisher, A. C. (2005). Will U.S. Agriculture Really Benefit from Global Warming? Accounting for Irrigation in the Hedonic Approach. The American Economic Review, 95(1), 395-406.

Schlenker, W. and Michael J. Roberts. "Nonlinear Temperature Effects Indicate Severe Damages to U.S. Crop Yields under Climate Change". In: Proceedings of the National Academy of Sciences 106.37 (2009), pp. 15594–15598. doi: 10.1073/pnas.0906865106.

StatsNZ. (2018). Agricultural Production Survey. doi:http://archive.stats.govt.nz/survey-participants/a-z-of-our-surveys/agricultural-production-survey.aspx

Strauss, F., Formayer, H., Asamer, V. & Schmid, E. (2010). Climate change data for Austria and the period 2008-2040 with one day and km2 resolution. Universität für Bodenkultur Wien Department für Wirtschafts- und Sozialwissenschaften.

Tewari, R., Johnson, J., Hudson, D., Wang, C., & Patterson, D. (2013). Does Climatic Variability Influence Agricultural Land Prices under Differing Uses? The Texas High Plains Case %J Natural Resources. *Vol.04No.08*, 8. doi:10.4236/nr.2013.48062

Van Passel, S., Massetti, E., & Mendelsohn, R. (2017). A Ricardian Analysis of the Impact of Climate Change on European Agriculture. Environmental and Resource Economics, 67(4), 725-760. doi:10.1007/s10640-016-0001-y

Appendix 1

Table 1. Variables definitions

Variable and Unit of Measurement	Description	Source
Climate variables		
Autumn Temp (°C)	Autumn Average Temperature, 1981-2010	NIWA
Spring Temp (°C)	Spring Average Temperature, 1981-2010	NIWA
Summer Temp (°C)	Summer Average Temperature, 1981-2010	NIWA
Winter Temp (°C)	Winter Average Temperature, 1981-2010	NIWA
Autumn Precip. (mm/year)	Autumn Average Precipitation, 1981-2010	NIWA
Spring Precip. (mm/year)	Spring Average Precipitation, 1981-2010	NIWA
Summer Precip. (mm/year)	Summer Average Precipitation, 1981-2010	NIWA
Winter Precip. (mm/year)	Winter Average Precipitation, 1981-2010	NIWA
Soil characteristics		
Soil acidity	Measures of acidity (very low, low, moderate, high, very high)	LCR
Soil age	Measure of the age of the soil (young, old)	LCR
Soil content of calcium	Measure of the soil calcium content (low, moderate, high, very high)	LCR
Soil drainage	Measure of the soil's drainaige capability (poor, very poor, imperfect, moderate, good)	LCR
Soil flood risk	Measure of the soil's flood risk	LCR
Soil hardness	Measure of the soil's hardness (non-indurantion, very weak, weak, very strong)	LCR
Topography		
Slope (%)	Measure of the percent change in slope (in %)	LINZ
Socio-economic		
House prices (NZD)	Median house price in New Zealand Dollars	QV
Irrigated area (proportion)	Proportion of irrigated land	LCR
Others		
Road distance to " " (km)	Distance to local amenities	LINZ