ECONOMIC IMPACT OF GLOBAL WARMING ON THE URUGUAYAN RURAL SECTOR

IMPACTO ECONÓMICO DEL CALENTAMIENTO GLOBAL SOBRE EL SECTOR RURAL EN EL URUGUAY

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ABSTRACT

This paper is part of a larger study about global warming impact that is being conducted simultaneously in seven South American countries: Argentina, Brazil, Chile, Ecuador, Colombia, Uruguay, and Venezuela, with the support of Yale University (USA), World Bank, PROCISUR, and PROCIANDINO. The objective of this regional project is assessing the economic effects of climate change over the agricultural sector and, more specifically, rural poverty. The results presented herein correspond to the partial study carried out in Uruguay. Because its reduced size and climate variation, a satisfactory empirical estimation had to be achieved using a broader sample, with similar agro-ecological areas, that included data from Argentina as well. Nevertheless, it seems possible to get some general conclusions for Uruguay through such procedure. The results of this study suggest that changes in average precipitation levels but particularly in temperatures during the Summer, should affect productivity and therefore land value. If, as expected, changes derive in warmer climate conditions, the effects would be highly negative for agricultural sector. Commercial farms are more sensitive to climate changes than non-commercial farms. Likely, the latter could adapt better to changing climate conditions.

Keywords: climate change, Ricardian method, land productivity, land value

***JEL*:** I3, Q5, Q54

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RESUMEN

El presente trabajo forma parte de un amplio estudio sobre calentamiento global, llevado a cabo simultáneamente en seis países sudamericanos: Argentina, Brasil, Chile, Ecuador, Colombia, Uruguay y Venezuela, con apoyo de la Universidad de Yale (USA), Banco Mundial, PROCISUR y PROCIANDINO. El objetivo es evaluar los efectos económicos de un cambio climático sobre el sector agropecuario y, más específicamente, sobre la pobreza rural. Debido a su reducido tamaño y escasa variación climática, para la escala regional en que se desarrolló el proyecto, el análisis parcial para Uruguay se realizó a partir de una muestra más amplia, con zonas agroecológicas similares, que incluyó los territorios de Uruguay y Argentina. Los resultados sugieren que eventuales cambios en los niveles medios de precipitaciones pero fundamentalmente de temperatura afectarán la productividad agropecuaria, medida a través del valor de la tierra. Si, como cabe suponer, los cambios derivan en temperaturas promedio más elevadas, sobretodo durante el verano, los efectos, aunque probablemente diferentes según el tipo de explotación, serán altamente negativos para el sector. Los predios comerciales parecen ser más sensibles a los cambios climáticos que los no comerciales. Los predios pequeños de producción familiar tendrían una mayor capacidad de adaptación frente a los cambios en las condiciones climáticas.

Palabras clave: cambio climático, método ricardiano, productividad de la tierra, valor de la tierra.

INTRODUCTION

The results presented in this paper are part of a larger study about global warming impact conducted simultaneously in seven South American countries: Argentina, Brazil, Chile, Ecuador, Colombia, Uruguay, and Venezuela, with the support of Yale University (USA), World Bank, PROCISUR, and PROCIANDINO. The objective of the regional project entitled "Climate and Rural Property: Incorporating Climate into Rural Development Strategies" (SACRP from now on) is assessing the economic effects of climate change over the agricultural sector and, more specifically, rural poverty.

Data were collected in the seven countries through surveys, under a unique sampling protocol and using the same form. Aside from the analysis performed over the whole dataset by the SACRP project, a number of partial analyses, one per country, were conducted in order to understand the specifics of each country or even subregions within countries.

The results presented herein correspond to the partial study carried out in Uruguay. It attempts to bring some light over the potential economic effects of global warming on the Uruguayan agriculture sector

Because its both reduced size and climate variation, a satisfactory empirical estimation had to be achieved using a broader sample that included Argentinean data as well. Nevertheless, taking into consideration that the distribution of the Uruguayan observations, for most of the variables, fell close around the averages of the whole two-country sample, it seems possible to get some general conclusions for this country through such procedure.

Theoretical Framework and Estimation Methods

Ricardian Model

The Ricardian method finds its roots in the Ricardian concept of land rents. According to this, money value of farms would reflect the present value of future net productivity. Mendelsohn, Nordhaus and Shaw (1994) first investigated the economic impact of climate on U.S. land prices using this method. Since then, the use of this method has been debated (Cline, 1996; Darwin, 1999; Mendelsohn and Nordhaus, 1996, 1999a, 1999b; Quiggin and Horowitz, 1999) and a number of studies with empirical application have been referenced in the literature (Dinar *et al.*, 1998; Mendelsohn and Dinar, 1999; Mendelsohn *et al.*, 1999; Kumar and Parikh, 2001; Reinsborough, 2003). As a more recent antecedent, Seo, Mendelsohn, and Munasingue (2005) presented results of climate change impacts in Sri Lankan agriculture, using the Ricardian method.

A model with these characteristics can be stated as:

$$P_{Land} = \alpha + \sum_{h=1}^{H} \beta_h F_h + \sum_{h=1}^{H} \delta_h F_h^2 + \sum_{j=1}^{J} \gamma_j Z_j + \sum_{k=1}^{K} \vartheta_k G_k + \varepsilon \quad . \qquad (1)$$

The observations subscript is omitted for simplicity. The left-hand side of (1) is the dependent variable, P_{Land}, measured in US dollars per hectare. In the right-hand side, F_h and F_h^2 represent linear and quadratic climate variables: temperature and precipitation (H = 2); Zj represent a set of soil description variables; G_k is a set of socioeconomic and demographic variables that characterize the farm and its owner, including his/her family. There could be $2\times H + J + K + 1$ coefficients to be estimated, represented by α, β_h, δ_h, γ_j, and ϑ_k; the term ε represents the residuals, assumed to be IID(0, σ^2I).

The model was estimated by Ordinary Least Squares (OLS) and corrections for heteroscedasticity were done when necessary, using a heteroscedasticity-consistent covariance matrix estimator (White, 1980). Price elasticity at the means was calculated with respect to changes in both temperature and precipitations to measure the marginal effects of the climate variables over land value.

$$\xi = \frac{\partial P_{Land}}{\partial F_h} \times \frac{\overline{F}_h}{\overline{P}} = \left(\beta_h + 2 \times \delta_h \overline{F}_h\right) \times \frac{\overline{F}_h}{\overline{P}_h}. \quad (2)$$

Perception about climate change

Respondents of the surveys were asked if they noticed any long-term shifts in climate, such as changes in temperature or rainfall. Hence, farmers' perception about climate change can be captured through a model that follows this general form:

$$d^* = \mathbf{v}'\theta + u^*. \quad (3)$$

The dependent variable d^* is a latent unobservable variable. Instead, what is observed is its realization d, a binary variable, which takes the value $d = 1$ (yes, climate change was perceived) when $d^* > 0$ and $d = 0$ ((climate change was not perceived) when $d^* \leq 0$. Socioeconomic characteristics of the farm, its owner, and his or her family where used as independent variables, in order to identify if any of these traits were able to explain, in part, this perception. Vector **v** contains the independent variables presumed to affect the decision. The model can estimated by maximum likelihood, where u^* follows a logistic distribution.

Projections of climate change impacts

The potential impact of climate change (global warming) was assessed through the analysis of different scenarios, each having some probability to occur, derived from climate models. In the first approach, eight extreme possibilities were considered to visualize the effects of a potential climate change. The first two scenarios considered an increase in the mean temperature (+2.5 and +5.0ºC, respectively), *ceteris paribus*. The next two scenarios considered changes in annual rainfall (+10% and –10%, respectively) with temperature held constant. The last four scenarios considered combinations of warming and precipitation change (+2.5ºC with +10% PP; +5.0ºC with +10% PP; +2.5ºC with –10% PP; and +5.0ºC with –10% PP).

In the second approach, three different possible scenarios derived from three AOGCM models (CCC, CCSR, and PCM) were taken to observe the evolution of these effects over three different time periods: 15 years (by year 2020), 55 years (by year 2060), and 95 years (by year 2100).

In all cases, climate change impact (*CCI*) is measured as the difference between land value in the future scenario (P_{L1}) and land value in the current scenario (P_{L0}). The results may be presented in relative terms (percentage) with respect to the initial situation:

$$CCI = \%\Delta P_L = \frac{(P_{L1} - P_{L0})}{P_{L0}} \times 100 . \quad (4)$$

Data collection and sampling

The lack of sufficient climate (temperature and precipitations) and geographic (soils and topography) variability when data from Uruguay is considered at the regional level prevents us from conducting empirical estimation using this dataset alone, even when the sample size is adequate in terms of degrees of freedom. For this reason, the analysis of global warming effects in Uruguay was performed through a wider sample that included the data from Argentina as well. A dummy variable named codadm0 was used to identify the country (0 - Argentina; 1- Uruguay).

The basic statistics calculated from the Uruguay subset showed that sampling distribution for this country falls in the middle ranges of the complete Argentina-Uruguay dataset distribution, at least for most variables. Thus, inferences from the results observed in a close range over the means in the whole sample might well represent the conditions for Uruguay.

The complete date set used in this study comprised 577 observations, 175 of which correspond to farms surveyed in Uruguay; the remaining 402 observations represent Argentinean farms. The 175 farms surveyed in Uruguay were evenly distributed all over the country.

Information reported in the surveys regard farm figures and facts (farm type, crops and livestock production, land values, revenues and costs, facilities, among others) as well as demographic and socioeconomic characteristics of farmer's household (education, age, gender, years farming, household size, among others). Questions about farmers' perceptions about climate change were also included in the questionnaire.

Soil data at the district level, including texture and slope, were extracted from FAO digital soil map of the world CD-ROM (FAO, 1996) and used as control variables. Climate data came from two sources: temperature data originated from US Defense Department Satellites whereas precipitation data was taken from ground station interpolations by the World Meteorological Organization.

Description of the variables

Four versions of the Ricardian model derived from the combination annual and seasonal climate data with type of farm, were included in this study.

- Model 1: Annual climate regression without discriminating the type of farm.

- Model 2: Seasonal climate regression without discriminating the type of farm.
- Model 3: Annual climate regression identifying the type of farm (commercial and small).
- Model 4: Seasonal climate regression identifying the type of farm (commercial and small).

A number of variables were created for the specific estimation procedures performed in this research. The land value in US dollars per hectare (landval1ha) was used as dependent variable in all Ricardian regressions. A binary variable (climshift1) which accounts farmers' perception of long-term shifts in climate was used as dependent variable for the logistic model.

The variables utilized in the different estimation procedures are defined in Table 1. Both temperature and precipitation were used as climate variables (*F*), included in different ways: as annual averages and season averages (Winter and Summer). In addition, interactions of the two variables with the type of farm (commercial and non-commercial or small farm) were considered. In all cases, they were stated in both linear and quadratic form.

Soil variables were constructed using the unit soils used by FAO (1996). A dummy variable identifies the presence of a specific dominant soil in the observation. Another binary variable (water_src) indicating the source of the water used in the farm for crop and pasture production was included in the logistic model.

All models also included different demographic and socioeconomic data as control variables, which characterize the farmer and her family (farm size, household size, years as farmers, age and sex, as well as education level of the household head, presence of electricity, telephone, and personal computer). However, not all the control variables were finally used on each estimation procedure.

RESULTS AND DISCUSSION

Basic statistics

One hundred and seventy five observations out of 577 correspond to farms surveyed in Uruguay. Although only 5% of the respondents considered themselves as non-commercial farmers, a later analysis considering farm size and type of production allowed to categorize 36% of the farms as small farms, with an average size of 497 has. The remaining 64% were classified as medium and big commercial farms, with an average size of 818 has (Table 1).

Table 1. Basic statistics of the Uruguayan farms' sample.

Cuadro 1. Estadísticas básicas de los predios muestreados en Uruguay.

Variable	Statistics	Small	Commercial
sizeha	Average size of the farm (has)	497	818
farmyears	Average years as farmer (sample mean)	17	22
age_head	Average age of the household (years)	51.4	51.2
female	Farms where the head is a female person	0%	6%
educ_head	Average level of education (years)	14	14
educ_head	Maximum level of education (years)	21	24
hhsize	Average size of the household (#)	3.63	3.98
elect_dum	Farms with electricity (%)	37.5%	80,8%
tel_dum	Farms with telephone (%)	87.5%	90.4%
con_dum	Farms with personal computer (%)	12.5%	57.5%
landval1ha	Average value of land (US$/ha)	490	928
landval2ha	Land value (includes buildings, livestock, equip.) (US$/ha)	627	1,754
climshift1	Farmers who perceived climate changes (%)	63%	69%

On average, commercial farmers have more years working as farmers (22 against 17) although their similar age (51 years). Only 6% of the commercial farms are managed by female persons, while none of the small farms has a woman as its head. In addition, the average education level was similar (14 years) which means that, in general, household head completed high school level. However, highest levels of education (postgraduate studies) were observed in commercial farms. The size of the household was slightly greater for commercial farms than for small farms.

With regard to the available facilities in the farm, 37.5% of the small farmers have electricity. For commercial farms, this percentage rises to almost 81%. Although still higher for non-commercial farms, the proportion of farmer that have access to telephone does not show such a difference, being 87,5% for the former and 90.4% for the later. Finally, when asked for the use of personal computers in the farm, the proportion of positive responses was only 12.5% in the case of small and 57.5% in the case of commercial farms.

Sample average land value, in US dollars per hectare, was $490 for small farms and $928 for commercial farms. This difference widens when buildings, livestock, and equipments, are considered in the land value, reflecting the fact that commercial are more capital intensive than small non-commercial ones. In this case the value rises to $627 (an increment of 30%) while achieving $1,754, in the case of commercial farms (89% rise).

Estimation of Ricardian model

Due to the lack of space, only the results of the seasonal climate regression model (Model 4), identifying the type of farm (commercial and small) are presented in this paper. Nevertheless, for the purposes of this discussion, it is worthy to start wth some comments about the results of the remaining models. The complete results are available from the authors upon request.

When climate data averages at the annual levels were considered, without discriminating between farms, both temperature and precipitation showed significant effects on land value. Both climate variables showed a positive but decreasing relationship with the land value level. Changes in annual mean daily temperature appear to have a stronger effect over land values than changes in the annual mean of monthly rainfall, according with the magnitudes of the coefficients.

When seasonal figures were considered (Model 2), both Summer and Winter temperatures, and Summer and Winter precipitations, still showed positive linear coefficients but negative quadratic coefficients. Again, the magnitudes of the temperature coefficients are greater than those for precipitation suggesting a stronger effect of temperature changes over land values compared to changes in rainfall levels. However, the critical season seems to be the Summer, especially when most likely future scenarios involve warming. Model 3 and Model 4 were estimated in order to discriminate the potential effects of climate changes over different type of farms. This is carried out through the interaction of temperature and precipitation variables and type of production entity, that is, commercial farms and small non-commercial farms. Thus, Model 3 resembles Model 1 (annual climate variables) with the difference that climate coefficients were estimated for each type of farm (commercial and small). On the other hand, Model 4 is similar to Model 2 (seasonal climate variables) but, again, climate coefficients were estimated for each type of farm.

The results of Model 3 showed that climate effects over land values are similar when farm types are identified than when they are not. That is, both temperature and precipitation coefficients are positive in the linear terms and negative in the quadratic terms, for both commercial and small non-commercial farms. Again, temperature is the variable exhibiting the strongest effects on land value, regardless the type of farm.

Table 2. Results of Ricardian regression, Model 4: aggregate annual regression i(small & commercial).

Cuadro 2. Resultados de la regresión ricardiana, Modelo 4: regresión con datos anuales agregados (predios pequeños & comerciales).

Variable	Description	Estimate	Std. error	t Value	Pr > │t│
Intercept	Intercept term	-4914.830	1376.370	-3.57	0.000 ***
codadm0	Country (1=Uruguay; 0=Argentina)	-1110.360	246.274	-4.51	0.000 ***
te_sumxd	Summer temperature(ºC) × CF	614.420	157.444	3.90	0.000 ***
te_sum2xd	Squared Summer temp.(ºC) × CF	-23.973	5.325	-4.50	0.000 ***
pr_sumxd	Summer precipitation (mm) × CF	19.936	8.721	2.29	0.023 **
pr_sum2xd	Squared Summer precip. (mm) × CF	-0.114	0.051	-2.24	0.026 **
te_winxd	Winter temperature(ºC) × CF	514.723	177.515	2.90	0.004 ***
te_win2xd	Squared Winter temp.(ºC) × CF	-18.051	7.005	-2.58	0.010 **
pr_winxd	Winter precipitation (mm) × CF	-3.847	4.581	-0.84	0.402
pr_win2xd	Squared Winter precip. (mm) × CF	-0.013	0.015	-0.88	0.377
te_sumxs	Summer temperature(ºC) × NCF	461.886	162.449	2.84	0.005 ***
te_sum2xs	Squared Summer temp.(ºC) × NCF	-12.257	4.637	-2.64	0.009 ***
pr_sumxs	Summer precipitation (mm) × NCF	27.228	4.447	6.12	0.000 ***
pr_sum2xs	Squared Summer precip. (mm) × NC	-0.118	0.022	-5.31	0.000 ***
te_winxs	Winter temperature(ºC) × NC	7.141	98.681	0.07	0.942
te_win2xs	Squared Winter temp.(ºC) × NC	-4.802	3.981	-1.21	0.228
pr_winxs	Winter precipitation (mm) × NC	9.909	2.282	4.34	0.000 ***
pr_win2xs	Squared Winter precip. (mm) × NC	-0.044	0.009	-4.78	0.000 ***
popdens	Population density	18.383	7.620	2.41	0.016 **
popdens2	Squared population density	-0.007	0.003	-2.32	0.021 **
tel_dum	Electricity (1=Yes; 0=No)	373.873	88.569	4.22	0.000 ***
fhpct	Humic Ferralsols (1=Yes; 0=No)	-6.442	1.375	-4.68	0.000 ***
hlpct	Luvic Phaeozems (1=Yes; 0=No)	-7.874	1.966	-4.00	0.000 ***
smpct	Mollic Solonetz (1=Yes; 0=No)	-15.714	4.518	-3.48	0.001 ***

Note: Asterisks denote t statistic significance at level: * 10%; ** 5%; *** 1%. CM indicates commercial farm whereas NC indicates small non-commercial farms.

When the effects of the extreme seasons (Winter and Summer) over both types of farms are considered, as in Model 4 the overall results were similar. However, it is observed in Table 2 that all estimated coefficients were statistically significant except those for the interaction of Winter temperature with small farms and Winter precipitations with commercial farms. In these cases, neither the linear nor the quadratic coefficients were different from zero at any significance level. Thus, specific conclusions for each farm type should be drawn with this regard.

Marginal effects of both temperature and precipitation (annual and seasonal) are presented in Table 3. The land value elasticity with respect to climate variables, for all farms and for each type of production, commercial and small non-commercial, was computed at the means, as stated in equation (2). As noted, the marginal effects of Winter temperature for small farms, and Winter precipitation for commercial farms and for all farms considered together are not presented, since they were computed from statistically insignificant coefficients.

In any case, it should be noted that marginal effects are not constant over the range of temperatures and precipitations, due to non-linear effects of these variables. This is illustrated in Figure 1 for temperature and Figure 2 for precipitation. It can be observed that land value curves for temperature are more concave (steep) than those for precipitation, showing that the magnitudes of the elasticities are indeed higher.

Table 3. Elasticities at the mean of land value with respect to climate variables by type of farm.

Cuadro 3. Elasticidades en la media del valor de la tierra con respecto a las variables climáticas, por tipo de predio.

Farm Type	**Temperature**			**Precipitation**		
	Summer	**Winter**	**Annual**	**Summer**	**Winter**	**Annual**
Commercial	-10.8688	0.9590	-4.0439	-0.6082	n/s	-0.2517
Small	-2.2519	n/s	-3.7846	0.0771	0.1831	0.1395
All Farms	-7.5811	0.0006	-4.2542	-0.4464	n/s	-0.0571

n/s: computed elasticity from non-significant estimated coefficients.

The first conclusion drawn from the appraisal of the marginal effects is that the strongest effect comes from potential changes in average daily temperature, particularly Summer temperatures, regardless the type or farm. For instance, a 10% increase in annual mean temperature would derive in a reduction of land productivity, measured through land value, of more than 40%, ceteris paribus. If this increment occurs on Summer temperatures, the downfall in land value is likely to account by more that 75% of its current value. If the increment is observed over Winter temperatures, ceteris paribus, negligible effects should be expected.

Second, although all types of farms might be severely affected by warmer Summers, commercial farms will probably suffer more negative effects, compared to small non-commercial ones. The estimated potential prejudice from a 10% increase in average Summer temperature could be as big as 100% decrease in land value. In other words, land productivity would be expected to be reduced to half its current value. In the case of small farms, this reduction should amount 20%. Warmer Winter seasons could have some benefits for commercial farms.

Perception of climate change and adaptation

Table 4 presents the results of the Logit regression model stated in expression (3), which permits a first characterization of those farmers who perceived the occurrence of climate change. Looking at the signs of the estimated coefficients, it is suggested, first, that Argentinean farmers perceived climate change more often than Uruguayan farmers. It is hypothesized that the explanation recalls on the fact that Argentina is a number of times bigger in size and also presents wide climate variations than Uruguay; thus, although climate factors are always a concern in agriculture farmers could be somewhat more sensible to these factors, in terms of constraints to production, in some areas of the former than in the latter.

Table 4. Results of Logit regression: Perception about ocurrence of climate change.

Cuadro 4. Resultados de la regresión logística: Percepción acerca de la ocurrencia de cambio climático.

Variable	Estimate	St. error	t value	Pr > |t|	Pr(*d* = 1)
Intercept	0.92401	0.16163	5.71691	0.000 ***	0.21053
codadm0	-0.56385	0.14551	-3.87501	0.000 ***	-0.12847
water_src	-0.33138	0.14926	-2.22011	0.026 **	-0.07550
farmyears	0.01095	0.00510	2.14562	0.032 **	0.00250
landval1ha	0.00021	0.00008	2.68514	0.007 ***	0.00005

Second, farmers whose main source of water was other than rainfall showed a higher perception of climate changes than farmers that depend mainly from rainfall. It may be possible that farmers who use irrigation as their main source for crops and livestock are more concerned with climate factors.

Third, respondents with more years as farmers tended to perceive climate changes more often than those with fewer years. Farmers with more years working in the farm have a wider range of years to make the comparison and therefore are more likely to have perceived any potential change in climate variables, such as temperature and rainfall.

Fourth, farmers located in more productive fields, in terms of land values, perceived the occurrence of climate changes more often than occupants of cheaper lands.

However, nothing further can be said from the magnitudes of the estimated coefficients alone. So, last column shows the marginal contribution of each independent variable to the probability that a given farmer would have perception about long-term climate changes. According to the results, for instance, if the respondent to this question is an Argentinean farmer instead of Uruguayan, the probability of a positive answer will increase in 13%, ceteris paribus.

On the other hand, if the main source of water of the farm surveyed is rainfall, the probability that the respondent will report that perceived long-term climate changes will diminish in 7,5% if compared to a farm that uses irrigation as its main source, all other things equal. In the same sense, one additional year as a farmer would increase the probability of a positive answer in 0.25 %.

Finally, each increase by a hundred dollars per hectare in the value of the land will derive in an increase in the probability that the owner perceives long-term climate change by 0.5%.

Future escenarios of climate change

Climate conditions in Uruguay can be defined as moderate. Mean temperatures for all the country reach 17.5°C, with a maximum isotherm of 19.0°C over the Northwestern region of the country and a minimum of 16.0°C over the Atlantic coast, in the Southeast. Annual accumulated precipitations average 1,300 mm, with a maximum isohyets of 1,600 mm in the Northern region and a minimum of 1,100 mm in the coast of the Río de la Plata (DNM, 2006) in the South.

The effects of the eight climate change scenarios in Uruguay are presented in terms of percentage change of land value estimated with equation (4). Due to lack of space, the details of calculations were omitted but are available from the authors upon request. Results were tabulated, with the scenarios as row headers and type of production entity as columns headers, in Table 5.

Table 5. Global warming effects under different scenarios.

Cuadro 5. Efectos del calentamiento global bajo diferentes escenarios

Scenarios of climate change (Warming)	%Δ on Land value by Type of farm	
	Commercial	**Small non-commercial**
+ 2.5 ºC Δ in Temperature	- 72.43 %	- 103.11 %
+ 5.0 ºC Δ in Temperature	- 171.93 %	- 247.52 %
+ 10 % Δ in Precipitation	- 4.98 %	0.16 %
– 10 % Δ in Precipitation	0.12 %	- 4.06 %
+ 2.5 ºC Δ in Temp. & + 10 % Δ in Precipitation	- 77.41 %	- 102.94 %
+ 5.0 ºC Δ in Temp. & + 10 % Δ in Precipitation	- 72.31 %	- 107.17 %
+ 2.5 ºC Δ in Temp. & – 10 % Δ in Precipitation	- 176.91 %	- 247.35 %
+ 5.0 ºC Δ in Temp. & – 10 % Δ in Precipitation	- 171.81 %	- 251.58 %

The first two scenarios consider increments in temperature (+2.5ºC and +5.0ºC). The effects of a warmer climate are prejudicial for both commercial and small farms, and it was shown that commercial farms in the sample were more sensitive (elastic) to temperature changes. However, since mean land values of non-commercial farms were smaller than commercial, downfalls in land values are relatively more important for the former than for the latter.

In comparison, the effects of potential changes in the average monthly precipitation levels are expected to be mild, if occurred alone. The direction of the effects depend on the starting rainfall levels where a particular farm is located, as observed in the scenarios three and four, which consider only changes in precipitation levels.

The occurrence of scenarios combining warming with changes in rainfall is presented in the last four rows of the table. Regardless of the farm type, increments of precipitation levels in the order of, say 10%, become important in muffling the negative effects on land values when considering rises in temperature of more than 2.5ºC above current means. On the opposite, if precipitation levels fall in the same proportion, then an increment in average temperatures of 2.5ºC should be as negative as an increment of 5ºC.

As explained before, although the estimated magnitudes of land value elasticities with respect to temperature and precipitation are smaller for non-commercial farms than for commercial farms, a specific downfall that is similar in value will represent a larger proportion of the value for the former than for the latter.

Nevertheless, the scenarios discussed above represent extreme situations, not very likely to occur in the coming century. Thus, under the SACRP project framework, three scenarios from Atmosphere Ocean General Circulation Models (AOGCM) were evaluated: Canadian Climate Center (CCC), Center for Climate System Research (CCSR), and Parallel Climate Model (PCM). Three time periods (2020, 2060, 2100) were considered in terms of their economic impact on the agricultural sector. The results are reported in Table 6.

Table 6. Global warming effects for three different AOGCM models.

Cuadro 6. Efectos del cambio global para tres diferentes modelos AOGCM.

AOGCM Models	Commercial			Small Non-Commercial		
	2020	2060	2100	2020	2060	2100
CCC	61.59%	7.85%	-104.63%	54.05%	0.35%	-111.92%
CCSR	79.27%	51.62%	33.48%	82.28%	48.01%	14.99%
PCM	85.45%	70.71%	46.30%	83.62%	62.62%	27.62%

The CCC model represents the worst case scenario. In the case of Uruguay, it represents an increment of one degree Celsius in the next 15 years, with respect to current mean temperature. By year 2020, annual mean temperature is expected to average 18.6ºC. According to this model, it is expected a mean temperature of 19.6 ºC by 2060 and 21ºC by 2100. Summer daily temperatures, currently averaging about 22ºC for Uruguay, would rise to an average of 25ºC, 26.1ºC and 27.3ºC, respectively, whereas Winter daily temperatures, currently around 12.0ºC, would reach 12.9ºC, 13.5ºC and 15.5ºC in the same periods. Currently, average monthly accumulated precipitation is in the order of 100 mm. The CCC model forecasts an increase in rainfall levels to 112 mm by 2020, 131 mm by 2060, and 157 mm by 2100.

The mildest scenario, in terms of temperatures, is represented by the PCM model. The increments in temperature will position the annual values of daily temperature at 17.9ºC by 2020, 18.4ºC by 2060, and 19.3ºC by 2100. These magnitudes are similar to those projected by the CCSR model (17.9ºC, 18.7ºC, and 19.5ºC, respectively). The main difference is that the latter estimates higher temperatures during the Summer than the former. Daily temperatures during this season are expected to average 23.7ºC by 2020, 24.3ºC by 2060, and 25.1ºC by 2100, for the CCSR model. In contrast, PCM consider average temperatures of 21.5ºC, 22.2ºC, and 22.6ºC, respectively, during the Summer. With respect of Winter temperatures, the magnitudes projected by the CCSR model for the same periods are 11.8ºC, 13.2ºC, and 14.0ºC, whereas for the PCM model the average magnitudes are 14.1ºC, 14.5ºC, and 15.5ºC, respectively. The results obtained in this study suggest that the global warming forecasted by all the AOGCM is expected to affect negatively the agricultural sectors in Uruguay and Argentina. Land productivity, measured as land value in US dollars per hectare would decrease up to 62% of its current value, for commercial farms, and up to 54% in the case of small non-commercial farms in the next 15 years. Even for the best scenario considered in this study it is expected that land values may diminish by 15% of current values.

Conclusions and principal remarks

The obtained results suggest that changes in both temperature and precipitation might severely affect productivity and therefore land value. The effects would probably be different according to the type of production entity. Although the magnitudes would be different in the presence of different possible future scenarios, the effects are expected to derive in net losses for producers. According to the results obtained in this research, commercial farms appear to be more sensitive to climate changes; this suggests that small non-commercial farmers could adapt better to changing climate conditions.

This is the first study carried out for the Atlantic Southern region of South America and conclusions should be managed with caution. Using current land values for different climate zones to forecast the magnitude of potential land value changes due to climate shifts is probably a good approach to understand this problem. However, these models may not capture all the complexity of each ecosystem and, for instance, its ability to react and adapt to the changing conditions, absorbing at some degree the negative effects. More research is needed in order to countersign and give more confidence to these results.

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Figure 1. Effect of temperature shifts over land value.

Figura 1. Efecto de los cambios de temperatura sobre el valor de la tierra.

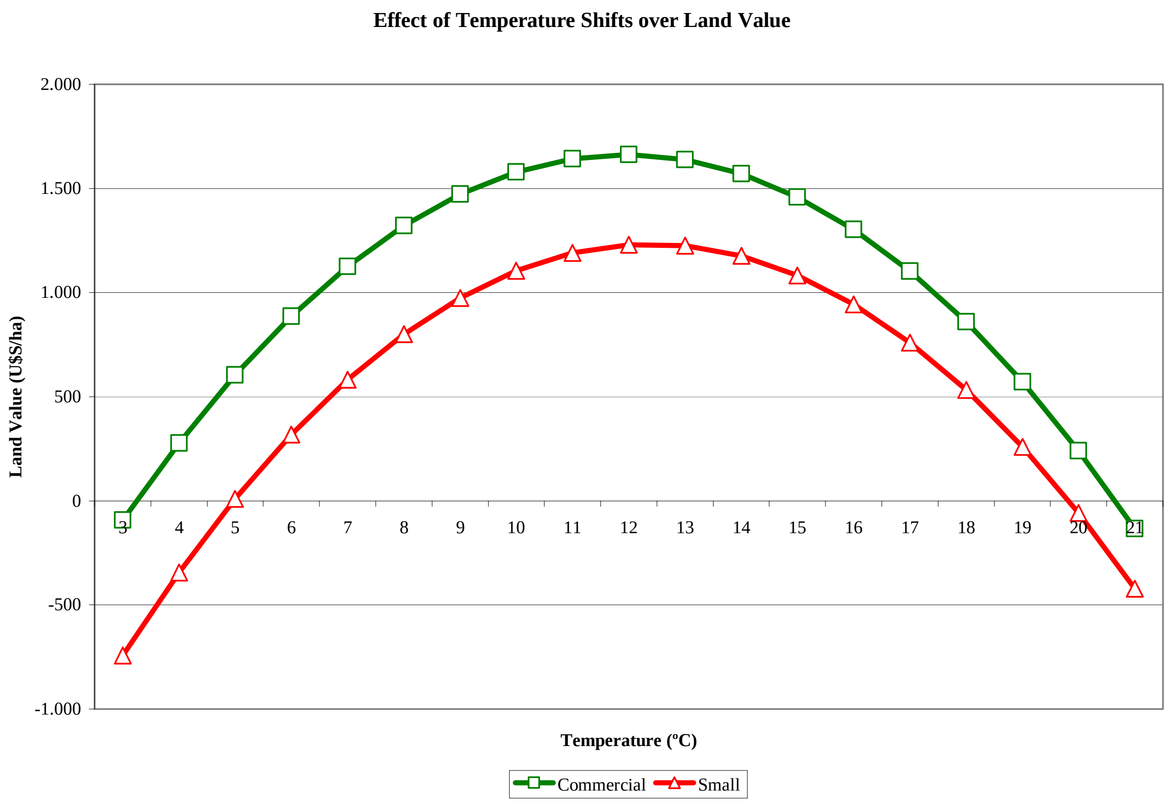

Figure 2. Effect of precipitation shifts over land value.

Figura 2. Efecto de los cambios en el nivel de las precipitaciones sobre el valor de la tierra.