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Research Article

Impact of Climate Variability on Farms Revenue in High Vulnerable Agro Climatic Zone of Tamil Nadu

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Abstract

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. The aim of the study is to gauge economic impact of climate variability on farms revenue in high vulnerable agro climatic zone of Tamil Nadu. Data were collected from TNAU meteorological department Coimbatore, about 180 samples were collected randomly to conduct this study. The results indicated that temperature (kharif and summer) and rainfall (kharif, rabi and summer) had significantly influenced net revenue in irrigated farms and rain-fed farms. Temperature and precipitation were found to have significant impact in rain-fed farms and irrigated farms and the result suggests that irrigation is the efficient adaptation method. So it is important to augment irrigation capacity to tide over the negative impact of climate change in agriculture.

Keywords: Climate variability, Ricardian, Temperature, Rainfall, North Western Zone

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Introduction

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. United Nations Framework Convention on Climate Change (UNFCCC) defines “climate change” as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” It is long-term continuous change (increase or decrease) compared to average weather conditions or the range of weather. Climate change is slow and gradual, unlike year-to-year variability, is very difficult to perceive without scientific records. Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability). (IPCC 2001). Common drivers of climate variability include El Niño and La Niña events, which are shifts of warm, tropical Pacific Ocean currents that can dramatically affect Michigan’s winters. El Niños give us milder, less snowy winters, while La Niñas give us colder, snowier winters. Other drivers of climate variability include volcanic eruptions and sunspots. Sometimes climate varies in ways that are random or not fully explainable. The impacts of climate change is classified into direct, i.e., loss of life, livelihoods, assets, infrastructure, etc., from climatic extreme events and indirect pertaining to its effect on economic growth. It is foreseen that the continuing climate variation would alter the sectoral origins of growth, and with this, the ability of the poor to engage in the non-farm sector. Furthermore, it will increase inequality and reduce the poverty elasticity of growth. It is reported that, the impact of climate change on Indian agriculture would be small in near future, but in long run the Indian agriculture may be seriously affected depending upon season, level of management and magnitudes of climate change (Rajeevan, 2013). Many past studies related to climate change reported that, there is negative effect of climate change on agriculture. It may affect production of agricultural crops (Hulme, 1996). Apart from climate change impact, climate variability is also having serious impact on Indians agricultural production and consequently, on the country’s gross domestic product (GDP). A striking result from agriculture science research is that, climate variability alone i.e. without change in mean temperature, can cause decrease in crop yield (Jayaraman & Murari, 2014). Many precedent studies (Parthasarathy *et al.,* 1985; Parthasarathy *et al.*, 1992; Selvaraju 2003; Krishna Kumar *et al.*, 2004; Gadgil *et al.*, 2006) showed a strong effect of Indian summer monsoon rainfall on level of agricultural production and on country's GDP. With this background the main objective of this study is to gauge economic impact of climate variability on farm revenue in high vulnerable agro climatic zone of Tamil Nadu.

Methodology

Tamil Nadu state is classified into seven distinct agro-climatic zones namely North Eastern zone, North Western zone, Western zone, Cauvery Delta zone, Southern zone, High Rainfall zone and Hilly zone based on rainfall distribution, irrigation pattern, soil characteristics, cropping pattern and other ecological, social and physical status. Of the five zones, the North East zone and Southern zone occupies the first two places with 24 per cent and 20 per cent of the total area followed by Cauvery delta (15 per cent), North West (14 per cent), Western zone (12 per cent) and hilly zones which occupy less than four per cent of the geographic area. Based on the vulnerability index, the present study focuses on the North western (high vulnerable) of Tamil Nadu. The North West zone encompasses Dharmapuri, Krishnagiri, Salem and Namakkal districts. These districts comprise 8, 10, 20 and 15 blocks respectively. All the districts in the North Western zone have automatic weather stations, installed at block level and monitored by Tamil Nadu Agricultural University. Since the farmers had access to weather related information from the block level automatic weather stations, the sample farmers were selected from those blocks. The selection of the respondent farmers was selected by random sampling.

Data were collected through a well structured and pre tested interview schedule from 180 randomly selected sample farmers distributed equally at the rate of 45 sample farms in each district and nine samples for each automatic weather station in high vulnerable zone (North Western zone).

Ricardian analysis

The econometric approach used in this study is based on the Ricardian method to assess economic impacts of climatic changes, which allows for capturing adaptations farmers make in response to climate changes. The method was named after David Ricardo (1772 - 1823) because of his original observation that land value would reflect its net productivity. The principle is shown explicitly in the following equation:

$$LV = \sum P_i Q_i (X, F, H, Z, G) - \sum P_x X$$

Where LV is the value of land, Pi is the market price of crop i, X is a vector of purchased inputs (except land), F is a vector of climate variables, H is water flow, Z is a vector of soil variables, G is a vector of socio-economic variables and P_x is a vector of input prices (Robert Mendelsohn et al., 1994). It is assumed that the farmer chose X so as to maximize land value per hectare given characteristics of the farm and market prices. Depending on whether data are available, the dependent variable can either be the annual net revenues or capitalized net revenues (land values). Despite the wide use of the Ricardian approach, a major limitation in using land prices in climate response functions is the absence of well functioning land market in developing countries (Kumar & Parikh 2001; Kurukulasuriya *et al.*, 2006). The Ricardian theory is consistent when net revenue is used instead of land values because land values are based on the discounted stream of future net revenues (Kurukulasuriya et al., 2006). Similarly, Kavi Kumar and Parikh (2001) used annual farm-level net-revenue instead of land values, as land markets are not well functioning in India and no reliable data on land values is available. Following previous works such as Molua (2007), Eid *et al.*, (2007) and Mendelsohn *et al.*, (2007), the standard Ricardian model relies on a quadratic formulation of climate:

$$NR/ha = \beta_0+\beta_1F+\beta_2F^2+\beta_3Z+\beta_4G+\mu$$

Where, *NR* / *ha* represents net revenue per hectare, *F* is a vector of climate variables, *Z* is a set of soil variables, *G* is a set of socio-economic characteristics, and μ is the error term. Both linear and quadratic terms for temperature and precipitation are introduced. The expected marginal impact of a single climate variable on the land value and farm net revenue evaluated at the mean is:

$$E[dNR \text{ per } ha/df_1] = b_{1,i}+2*b_{2,i}*E[f_1]$$

The signs of the linear terms indicate the uni-directional impact of the independent variables on the dependent variable, the quadratic term reflects the non-linear shape of the net revenue of the climate response function. When the quadratic term is positive, the net revenue function is U shaped and when the quadratic term is negative the function is hill-shaped. Agronomic studies revealed that crops consistently exhibit a hill-shaped relationship with annual temperature, although the maximum of that hill varies with the crop. Ordinary least square (OLS) procedure using STATA 13.0 software was used to estimate the model. The advantage of this empirical approach is that the method includes both direct effect of climate on productivity and the adaptation response by farmers to local climate.

One of the important limitations of the Ricardian model is that it does not include price effects (Cline, 1996). If relative prices change because of the way climate change affects aggregate supply, the method underestimates or overestimates the impact depending on whether the supply of a commodity increases or decreases. This oversight leads to a bias in the calculations of producer and consumer surplus and hence to biased welfare calculations (Cline, 1996).

Mendelsohn and Tiwari (2000) argued that for a number of reasons it was difficult to include price effects. First, for most crops prices are determined in global markets and the prediction of what would happen to each crop needs global crop models. But global crop models are poorly calibrated, so it is difficult to predict what will happen to the global supply of any single crop in a new world climate. Secondly, the few global analyses completed so far Reilly et al., (1994) have predicted that the range of warming expected for the next century have only a small effect on aggregate supply. Third, if aggregate supply changes by only a moderate amount, the bias from assuming constant prices is relatively small. Thus, based on the above points, Mendelsohn and Tiwari (2000) argued that keeping prices constant is justified because it does not pose a serious problem in using the model.

Another criticism of the Ricardian model is that it does not take into account the carbon dioxide fertilization effect which can enhance crop yield by increasing photosynthesis and allowing more efficient use of water (Cline, 1996; Mendelsohn & Tiwari, 2000). However, in spite of these weaknesses, it can be used to analyze the impact of climate change on agriculture by fully considering the adaptations farmers make to mitigate the harmful effects of the change.

The absence of explicit inclusion of irrigation (Cline, 1996 and Darwin, 1999) argued in favour of inclusion of irrigation in the analysis. Several researchers (Mendelsohn *et al.*, 1994; Mendelsohn & Dinar, 2003) have attempted to address the problem by modeling irrigation. Following Kurukulasuriya and Mendelsohn (2006) this study analyzed the impact on dry land and irrigated land separately.

Results and Discussion

The econometric approach used in this study is based on the Ricardian method to assess economic impacts of climatic change, which allows for capturing adaptive capacity of the farmers in response to climate changes. The advantage of this approach is that the method includes both direct effect of climate on productivity and the adaptation response by farmers to local climate. The annual net revenue was the dependent variable. It was measured as the per hectare gross revenue less cost of the fertilizer, insecticide, herbicide, labour and other farming cost. The climate variables were defined in terms of three seasons like kharif, rabi and summer.

The Economic Impact of Climate Change on Agriculture in North Western Agro climatic zone

Descriptive Statistics

The basics summaries of the data set for the relevant variables of the study were presented in the **Table 1**.

On the average, net farm revenue per hectare for both irrigated and rain-fed farms was C 128395 and C 78650 respectively. The climate data namely temperature and rainfall and their mean values varied across the two category of farms. The average farming experience was 36.67 years and 12.56 years for irrigated and rain fed farmers respectively.

The Ricardian Regression Results

The determinants of net farm revenue (per hectare) are presented in the **Table 2**. In the Ricardian analysis two hypotheses were tested: First, net farm revenue per hectare is sensitive to climate; Second, irrigated and rain-fed farms have different response to climate.

These hypotheses were tested by estimating the following regressions: (i) The net revenues per hectare for all the farms (ii) The net revenue per hectare for irrigated farms (iii) the net revenue per hectare for rain-fed farms. The net revenue per hectare is the response variables.

They are regressed on climate and other control variables. The independent variables include both the linear and quadratic temperature precipitation and soil moisture term. The overall regressions showed that net-revenue per hectare models was significant at 1 per cent level and the adjusted R-squared value was 0.80, 0.89, 0.68 and for all farms, rain-fed and irrigated farms. Climate variables significantly influenced net revenue per hectare of irrigated farms and rain-fed farms. The results indicated that temperature (kharif, rabi and summer) and rainfall (rabi and summer) had significantly influenced net revenue in irrigated farms and rain-fed farms. In the case of linear form, kharif temperature and household size showed a significant and negative relationship with net revenue of the rainfed farmers but rabi temperature and experience showed a positive relationship. In the case of nonlinear relationship, all the squared terms for temperature and precipitation are significant and negative except kharif rainfall. It is evident that kharif temperature, rabi temperature, summer temperature, rabi rainfall and summer rainfall has a hill shaped relationship. It tells that the above mentioned variables are good only upto certain point after that it becomes harmful to the net revenue of the rainfed farmers.

Table 1 Descriptive Statistics: Variables for Net Revenue Regression Model

Variables	**Irrigated**		**Rainfed**		**Overall**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Net Revenue	78650.98	8154.07	128395.53	11154.41	109879.50	26150.02
Kharif Temperature (^{0}Celsius)	28.48	2.10	27.97	2.55	28.16	2.40
Kharif Temperature^2	815.57	119.15	788.81	141.20	798.77	133.71
Rabi Temperature	25.80	1.13	27.26	2.88	26.71	2.48
Rabi Temperature^2	666.76	58.44	751.07	161.94	719.69	139.06
Summer Temperature	28.22	2.64	29.34	2.65	28.93	2.70
Summer Temperature^2	803.38	147.30	868.00	157.34	843.95	156.43
Kharif Rainfall (mm)	171.74	89.83	244.69	149.75	217.53	135.12
Kharif Rainfall^2	37444.12	38638.85	82097.32	86913.44	65476.41	75799.04
Rabi Rainfall	532.21	188.89	428.91	168.66	467.36	182.92
Rabi Rainfall^2	318387.40	220205.09	212159.12	146234.63	251699.65	184149.36
Summer Rainfall	141.74	68.22	300.76	107.89	241.57	122.23
Summer Rainfall^2	24675.49	20823.64	101992.00	68600.44	73213.08	67149.80
Household size	4.05	0.47	5.43	1.12	4.92	1.14
Experience (years)	12.56	5.11	36.67	5.30	27.70	12.80

Table 2 Determinants of Net Farm Revenue per Hectare

	Irrigated		**Rainfed**		**Overall**	
	Coefficients	**Standard Error**	**Coefficients**	**Standard Error**	**Coefficients**	**Standard Error**
Intercept	**870578****	423111.64	-197509.18	173308.07	**736564.50*****	229247.62
Kharif Temperature (^{0}Celsius)	**-22738.21*****	4858.70	**16529.72*****	4023.19	-17316.30	9501.73
Kharif Temperature^2	**-2044.43*****	519.27	**292.16*****	70.05	296.21	165.27
Rabi Temperature	-52340.90	31867.73	-3463.20	4227.67	**-3767.65*****	1017.40
Rabi Temperature^2	964.84	614.38	49.10	81.77	**-696.94*****	196.67
Summer Temperature	**-4437.31****	1995.45	**-4058.18*****	1083.33	**-21133.86*****	7575.42
Summer Temperature^2	67.75	37.19	**-661.23*****	181.14	**-398.70*****	135.45
Kharif Rainfall (mm)	**1400.93*****	200.75	23.44	14.74	45.38	31.20
Kharif Rainfall^2	**-438.27*****	60.11	-0.03	0.02	-0.06	0.06
Rabi Rainfall	**2325.42*****	807.71	**754.06****	353.35	**848.25****	389.59
Rabi Rainfall^2	0.02	0.01	**-0.12*****	0.04	**0.11*****	0.04
Summer Rainfall	**933.04*****	268.35	**13.26****	6.52	**89.71*****	14.16
Summer Rainfall^2	**-37.69*****	9.29	**-0.01****	0.00	**-0.05*****	0.01
Household size	**7079.25*****	1500.65	-580.64	489.21	**3282.17*****	1224.15
Experience (years)	-6.92	144.49	-36.34	87.26	**538.00*****	207.70
Observations	60			120		180

Note: ***- Significant at 1 per cent level, ** -Significant at 5 per cent level

In the case of linear form, rabi temperature and summer showed a significant and negative relationship with net revenue of the irrigated farmers but kharif temperature, rabi and summer rainfall showed a positive relationship. In the case of nonlinear relationship, it is evident that kharif temperature, summer temperature, rabi rainfall and summer rainfall has a hill shaped relationship. It tells that the above mentioned variables are good only upto certain point after that it becomes harmful to the net revenue of the rainfed farmers.

Marginal Impact Analysis for Net Revenue Model

The marginal impact was estimated to assess the effect of temperature and precipitation on net revenue. **Table 3** showed the marginal impacts of climate variables on net revenue per hectare. The net revenue per hectare for rain-fed farmers fell at an average C22738 in kharif and C 4437 in summer per 1^0C increase in temperature, whereas the irrigated farmers' net revenue increased at an average of C 16530 in kharif season per 1oC increase in temperature, but it decreased at an average of C 4058 in summer. The results showed that higher temperatures reduced net revenue in rain-fed farming.

The results in the **Table 3** showed that higher temperatures reduced net revenue in rain-fed farming.

Table 3 Marginal impact of climate on net revenue

	Particulars	Rainfed	Irrigated	Overall
Temperature (^{0}Celsius)	Kharif Temperature	-22738.21	16529.72	-17316.30
	Rabi Temperature	-52340.89	-3463.19	-3767.64
	Summer Temperature	-4437.312	-4058.18	-21133.86
Rainfall (mm)	Kharif Rainfall	1400.93	23.44	45.38
	Rabi Rainfall	2325.42	754.06	848.24
	Summer Rainfall	933.039	13.25	89.70

The marginal effect of precipitation on net revenues also varies across farms. Increasing precipitation on rain-fed farms by 1 mm would increase the net revenue of rainfed farmers by C1401 in kharif, C 2325 in rabi and 933 in summer season. Similarly increasing precipitation on irrigated farms by 1 mm would increase the net revenue by C754 in rabi and C 13 in summer season. Increasing precipitation in all the season increases net revenue both farms. In the case of all farms, increasing precipitation by 1mm would increase the net revenue (C 848) rabi and (C 90) in summer season.

Conclusion and Policy Implication

In the Ricardian analysis, two hypotheses were tested: First, net farm revenue per hectare is sensitive to climate; second, irrigated and rain-fed farms have different response to climate. The analysis revealed that net-revenue per hectare was significant at one per cent level and the adjusted R-squared value was 0.76, 0.75, 0.74 and for all farms, rain-fed and irrigated farms. Climate variables significantly influenced net revenue per hectare of irrigated farms and rain-fed farms. The results indicated that temperature (kharif and summer) and rainfall (kharif, rabi and summer) had significantly influenced net revenue in irrigated farms and rain-fed farms. In the case of linear form of North Western zone, rabi temperature and summer showed a significant and negative relationship with net revenue of the irrigated farmers but kharif temperature, rabi and summer rainfall showed a positive relationship. Similarly in the case of linear form, kharif temperature and household size showed a significant and negative relationship with net revenue of the rainfed farmers but rabi temperature and experience showed a positive relationship. In the case of nonlinear relationship, it is evident that kharif temperature, summer temperature, rabi rainfall and summer rainfall has a hill shaped relationship. It tells that the above mentioned variables are good only upto certain point after that it becomes harmful to the net revenue of both rainfed and irrigated farmers. Temperature and precipitation were found to have significant impact in rain-fed farms and irrigated farms and the result suggests that irrigation is the efficient adaptation method. So it is important to augment irrigation capacity to tide over the negative impact of climate change in agriculture.

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