Impact of Climate Change on Agricultural Production in Nepal

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Abstract

This paper has adopted the Ricardian approach to measure the effect of climate change on crop production in Nepal using both cross-section and time-series climatic data. Net farm revenue is regressed on climate and socio-economic variables. The findings show that these variables have a significant impact on the net farm revenue per hectare. More specifically, relatively low precipitation and high temperature seem to have a positive impact on net farm revenue during the fall and spring seasons. Net farm revenue is likely to be increased by summer precipitation, but not by temperature. Marginal impacts are mostly in line with the Ricardian model, showing marginally increasing precipitation during summer and winter would increase net farm revenue, but reduce it by the quarter terms and temperature of these seasons. Marginally increasing precipitation would increase farm income in the hilly region, but reduce it in the Tarai region. Moreover, paddy and wheat yields are highly sensitive to the variability of precipitation. In conclusion, the impact of climate change on crop production seems to be varied in different climatic zones and crops.

Keywords: Climate change, agriculture, Ricardian approach, marginal impact, yield, Nepal

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1. Introduction

There is a growing concern about the effect of climate change on human life, as the scientific consensus grows that significant climate change is very likely to occur over the 21st century (Christensen and Hewitson, 2007). Climate change can have both direct and indirect impact on the general well-being of the people in which the community who primarily depend on natural resources such as agriculture and forest for their livelihood are likely to be most affected by climate change. With regard to agriculture, the general consensus is that changes in temperature and precipitation will result in changes in land and water regimes that will subsequently affect agricultural productivity (World Bank, 2003). There is an increasing concern about the impact of climate change on agriculture in developing countries with changing global climate (IPCC, 1996) and some attempts have been made to estimate this impact (Winter et al., 1996; Dinar et

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al., 1998; Kumar and Parikh, 1998; Mendelsohn and Tiwari, 2000). The impact of climate change on agriculture is therefore a matter of concern, particularly in the low income countries where a majority of people live in rural areas and depend on agriculture for their livelihood. An understanding of the impact of climate change on agriculture in the developing world is likely to be critical for its distributional effects as well as for formulating policies to reduce its magnitude.

This paper aims to assess the impact of climate change on agriculture in Nepal. The study on the impact of climate change on agriculture seems to be plausible in Nepal due to higher dependency of the people on agricultural sector for livelihoods. Previous studies on the impact of climate change on agriculture show a prediction of reduction in agriculture yields, particularly in tropical regions (Mendelsohn and Dinar, 1999; Kurukulasuriya and Rosenthal, 2003). Literature also shows that climate change would have serious impacts on agriculture in developing countries (Pearce et al., 1996; Tol, 2002; Mendelsohn et al., 2006). These studies further reveal that large adverse impacts on agricultural productivity, especially among the smallholders, can lead to a rise in poverty levels (World Bank, 2003). This paper thus intends to add the literature on the economics of climate change and contributes to the research on measuring the potential impacts of climate change in low income countries like Nepal.

Studies on the impact of climate change on agriculture have been increasing since the last decade in which two main approaches are widely used to assess the impact of climate change (Mendelsohn, 2007). O ne is simulation models that obtain parameters from controlled experiments and another one is cross-sectional analysis observing the (economic) system across different locations in order to determine how the system may adapt to different climatic conditions. The second method is widely known as the Ricardian approach which corresponds to the Hedonic Pricing of environmental attributes (Libert et al., 2009). This paper applies the second method to measure the effect of climate change using cross-section data of more than 656 households covering 14 districts of Nepal.

The paper is organized as follows. After providing a background to climate change in the introduction part, an overview of Nepalese agriculture is given in Section 2. Section 3 discusses the method applied to measure the impact of climate change on agriculture. Section 4 presents data sources and descriptive statistics, while the findings of econometric model are given in Section 5. The paper ends with conclusion in Section 6.

2. Overview of Nepalese Agriculture

Nepal is traditionally an agrarian country in which subsistence and semi-commercial agriculture dominate. About two-thirds of the economically active population is engaged in agriculture and agriculture sector contributes about one-third to the GDP. The variability of agricultural productivity due to climate change may have a significant impact on people depending on this sector, especially the poor and smallholders.

In Nepal, the total cultivated land area available is 2.97 million hectares, out of which, about 0.99 million hectare is cultivated. The average landholding is only 0.8 hectares and about 75 percent landholdings are of small size having less than 1 hectare (CBS, 2002). Although a small country with a large number of smallholders, Nepal is divided into three main climatic zones: alpine (area above 10,000 feet from sea level); temperate (area between 2,000 to 1,000 feet temperature varying between 32˚ F and 100˚ F); and sub-tropical (area between 200 to 2,000 feet with temperature 50˚ F to more than 100˚ F). Cropping patterns and crops also vary in different climatic zones (often called as agro-ecological belts). Rice and wheat are the major cereal crops in *Tarai*, i.e. southern plain area, while maize and finger millet are the main crops in the hills and the mountain region, especially grown on marginal lands with low productivity. In addition to traditional and staple crops, there is also a trend of cultivating other non-staple crops such as legumes, seasonal vegetables, potatoes, and other cash crops. However, agricultural commercialization has yet to occur in a tangible way. Policymakers and economists often believe that the major constraints in agricultural commercialization including low productivity are poor infrastructure and high dependency on weather. Due to lack of sufficient irrigation facility, Nepalese agriculture depends on monsoon rain. As the country belongs to the monsoon zone, the major staple crops are cultivated in this season; therefore the degree of rainfall has a significant impact on productivity and food security in Nepal. In a country where rainfed production system dominates, it is plausible to assess the impact of climate (e.g. precipitation and temperature) change on agriculture.

A study based on analysis of temperature trends in Nepal from 1977 to 1994 (collected from 49 stations), indicates a consistent and continuous warming during the period at an annual rate of 0.06^0C (MoENV, 2010). A similar study conducted by practical action (2009), looking at data from 45 weather stations for the period 1976-2005, indicates a consistent and continuous warming of maximum temperatures at an annual rate of 0.04^0C. These studies also indicate that the observed warming trend in the country is spatially variable.

3. Measuring Impact of Climate Change on Agriculture

This study has adopted the Ricardian method developed by Mendelsohn et al. (1994) to measure the value of climate in US agriculture. The analysis is based on the assumption of a direct cause and effect relationship between climate events and farm value. This technique is applied under the assumption of perfect competition in which Ricardo observed that land values would reflect land productivity at a site. In other words, the Ricardian method has been applied to assess the contribution of environmental conditions to farm income.

The Ricardian approach is preferred to the traditional estimation methods, given that instead of ad hoc adjustments of parameters characteristic of traditional approach, this technique automatically incorporates efficient adaptation by farmers to climate change (World Bank, 2003) and the use of net revenue reflects benefits and costs of implicit adaptation strategies. More specifically, Ricardian analysis incorporates substitution of various inputs and introduction of alternative activities each farmer has adopted in light of the existing climate (Kurkurlasuriya et al., 2006). The advantage in applying this model is that it is cost-effective, since secondary data on cross-sectional sites can be relatively easy to collect on climate, production, and socio-economic factors (Deressa and Hassan, 2009).

Despite its strengths, the approach as a cross-section analysis does not account for dynamic transition costs which can occur as farms move between two states. Likewise, Ricardian approach fails to fully control the impact of important variables that could explain variation in farm income. Another criticism of this method is the assumption of constant prices (Cline, 1996): the inclusion of price effects is problematic and the approach is weak here (Mendelsohn et al., 1994). These problems are significant but not fatal (Mendelsohn, 2001).

The analysis of climate change impact on agriculture applying the Ricardian approach uses net farm revenue as a dependent variable, a more robust measure, given the concern about equilibrium as it measures what the farmer currently receives without any concern for future returns, discounting capital or labor markets (World Bank, 2003). It is often mentioned in the literature that the Ricardian theory is consistent when net revenue instead of land value is used, because land values are based on the discounted stream of future net revenues (Kurkurulasuriya and Ajwad, 2006). As the data on the worth of net revenue are based on the cross-section survey of the year 2003/04, we ensure that the survey year is not influenced by any unusual, year-specific climatic activity that can otherwise be problematic if both prices and productivity are affected. Moreover, the Ricardian model seems to be plausible in developing countries due to insufficient research and experiments to apply other models such as agro-economic model (Seo et al., 2005).

The Ricardian approach followed by Mendelsohn et al. (1994, 1999) is the net revenue function of the form:

$$\Pi = \sum P_i Q_i (X, C, Z) - \sum P_x X \tag{1}$$

where Π is the net revenue per hectare, P_i is the market price of crops *i*, Q_i refers to the output of crop *i*, X is the vector of purchased inputs, C is a vector of climate variables, Z is a set of household and land characteristics, and P_x is a vector of input prices.

The Ricardian model is based on the assumption that farmer will maximize net farm revenues by choosing inputs (X) subject to climate and other socio-economic variables. In other words, this model is applied only when we expect farmers to be price takers in all markets. If this assumption is violated, the estimates of the function become meaningless from an economic point of view. Therefore, the standard Ricardian model is presented in a non-linear functional form where net farm value per hectare is regressed on climate and other socio-economic variables:

$$\Pi = \alpha_0 + \alpha_1 C + \alpha_2 C^2 + \alpha_4 Z + \mu \tag{2}$$

where μ is the error term.

Marginal values are often calculated to measure the marginal impacts of a change in climate variables and these values depend on the regression equation being used and the climate which is being evaluated. The expected marginal impact of a single climate variable, C_i on net farm income evaluated at the mean is:

$$E[\partial \Pi / \partial C_i] = \alpha_{1,i} + 2 * \alpha_{2,i} * E[C_i] \tag{3}$$

In this equation, the linear formulation of the model indicates uni-directional impact of independent variables on the dependent variable, while the nonlinear term shows the non-linear shape of the net revenue of the climate response function. It is noteworthy that the net revenue function is U-shaped in case of the quadratic term being positive and hill-shaped in case the quadratic term is negative.

In addition to the application of Ricardian model that allows both cross-section household and time series climate data, the study also performed a statistical analysis to determine the relationship between first difference of yield and climate variables (precipitation and temperature) from a period of 1975 to 2005 as applied by Nicholls (1997) and Lobell et al. (2005). The regression model is presented in the form:

$$\Delta Yield = \theta_0 + \theta_1 \Delta Preci + \theta_2 \Delta Temp + \omega \tag{4}$$

where ΔYield, is the first difference of yield of crops, such as paddy rice, wheat, maize, millet, barley, and potato; ΔPreci and ΔTemp are the first difference of average precipitation and temperature from the year of 1975 to 2005; θ_i s are the parameters to be estimated and ω is an error term.

4. Data Sources and Analysis

The study uses data obtained from Nepal Living Standard Survey 2003/04 (NLSS II) of the Central Bureau of Statistics, Nepal. The methodology used in the NLSS II was applied in more than 50 developing countries by the World Bank with the purpose of the Government to monitor progress in improving living conditions and to evaluate the impact of government policies and programs in the country. NLSS II is the second national survey of Nepal conducted by the Central Bureau of Statistics, Nepal with technical and financial support from the World Bank. The survey applied two-stage sampling procedure to select the sample for the first stage of the survey (e.g. NLSS 1995/96), in which the smallest administrative unit (i.e. the ward of Village Development Committees) was considered as the primary sampling unit (PSU) for the survey.

The NLSS II selected 275 wards with probability proportional to size (PPS) from each of the four ecological strata, where size was measured from the number of households in the ward. For NLSS II, the number of households in each PSU was fixed at twelve. The total sample size was 4008 households. However, only 3912 households consisting of 408 households from the mountain, 1968 households from the hills, and 1632 households from the *Tarai* (the southern plain) were enumerated because of insurgency during field survey. Out of 3912 households, this study uses only 656 households of 14 districts.

NLSSs provide a large number of data set about agricultural activities including information on demographic characteristics, household activities, both farm and off-farm, education and literacy, employment status in both farm and off-farm, wage rates and remittances covering all administrative and ecological zones. For the purpose of this study, information includes farm size, farm income, cost of inputs, household size, farm credit, distance to input market, and locational characteristics.

Table 1: Descriptive statistics

Variable	Variable description	Mean	Std. Deviation
Net farm income	Income from farm products plus sale of animal income and other products (in Nepalese Rupees)	2,572.86	251,82.64
Farm size	Farm land both owned and sharecropped (in hac)	0.74	1.06

Variable	Variable description	Mean	Std. Deviation
Irrigratio	Ratio of irrigated land to total farm land	0.51	0.44
Age	Household's Head age	46.47	14.38
Sex	Household Head sex	0.81	0.38
Edulevel	Years of schooling of household head	3.60	4.37
HHsize	Total number of household members	5.3	2.5
Mktcenter	Distance to input markets (walking hours)	0.41	0.25
Farm loan	Whether or not farmer received loan	0.62	0.48
w_preci	Winter precipitation (December-February) (mm)	23.24	9.22
w_temp	Winter temperature (December-February)(°C)	11.94	3.84
sp_preci	Spring precipitation(March-May) (mm)	57.26	33.63
sp_temp	Spring temperature(March-May) (°C)	22.36	5.44
su_preci	Summer precipitation (June-August) (mm)	589.59	298.75
su_temp	Summer temperature(June-August) (°C)	25.46	4.27
fal_preci	Fall precipitation (September-November) (mm)	78.29	45.55
fal_temp	Fall temperature (September-November) (°C)	21.51	4.95
Total number of observations 656			

In addition to household data, climate data such as temperature and precipitation were obtained from the Department of Hydrology and Meteorology, Ministry of Environment, Nepal where the data cover a period of more than 30 years - from 1964 to 2006. Crop yield data were collected from the yearly publication of the Ministry of Agricultural Development.

Descriptive statistics of the data used in this paper are given in Table 1. Net crop output[4] is the income received from farm products and by products of farm minus the total input cost including labor, fertilizer, seed, and other costs in Nepalese rupees. In other words, the total input cost is the cost paid by farm household either in cash or kind. Total farm land is the land used by the household for agricultural activities either owned, or rented, or sharecropped during the survey year and measured in hectare. Irrigation ratio is considered as the measurement of land quality which is common in these exercises.

The results of mean and standard deviation show that despite the small size of the country, there are wide variations in precipitation and temperature. Variations in means and standard deviations are also found in net farm income per hectare, age, and family size.

[4] This paper frequently uses both net farm income and crop output inferchangeably.

Figure 1: Yield and climate variables relationship, 1975 – 2005

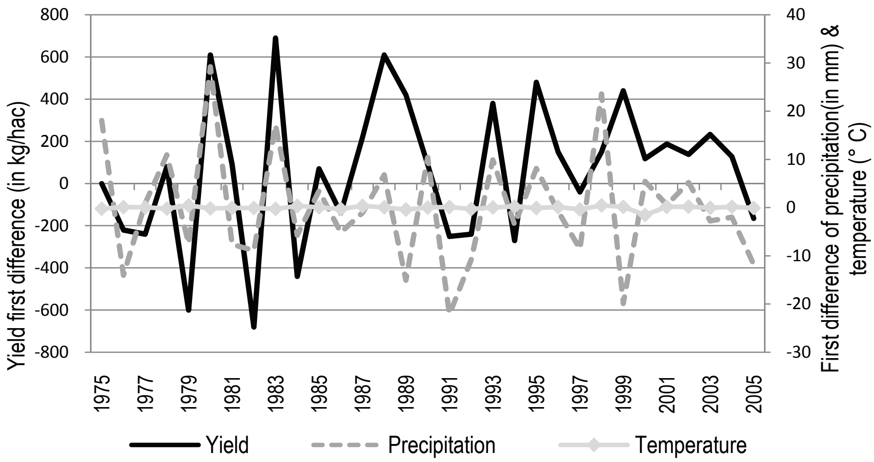

Figure 1 displays the relationship between total cereal crop yield and climate variables (precipitation and temperature), indicating that yield has been generally higher in the higher precipitation period, but not high during high temperature periods. The correlation coefficient (0.48, P<0.006) also reveals higher correlation between yield and precipitation, suggesting that cereal crop yield is highly sensitive to the variability of precipitation.

5. Econometric Results

The results of Ricardian models presented in Table 2 show both marginal impacts of the quarterly precipitation rates and temperature (in Model 1). However, some of quarterly temperature is omitted from the model due to the problem of collinearity. In Model 2, other socio-economic and land characteristics are included to find out the impact of such characteristics on the net farm revenue per hectare. As discussed earlier, the dependent variable of the model is net farm income per hectare (in Nepalese currency, i.e. NRs), while exogenous variables are precipitation rate, temperature, and other socio-economic characteristics. The second model includes farm size and ratio of irrigated land, assuming that irrigated land reflects the quality of the land; thus, the ratio of irrigated land is a proxy for land quality. Variables, such as distance to input markets and obtaining farm credit are often determining factors for agricultural productivity, particularly in the developing world. Hence, these variables are included in the analysis. In addition, socio-economic characteristics, such as household size, age, sex, and education level of the household head are also included in the model, implying that such variables do matter in the agricultural productivity. For instance, the age of the household is often used as a proxy variable for farm experience.

Prior to the econometric specifications, several diagnostic tests were carried out. First, normality test in residual by the Shapiro-Wilks asymptotic test was performed which was rejected, revealing that the estimated coefficients are consistent. Second, since the data set are cross-sectional and cover wide variation in the region, the probability of heteroscedasticity is high. So, heteroscedasticity test (Breusch-Pagan / Cood Weisberg) was performed and there was presence of heteroscedasticity. Then trobust standard errors are reported in the estimated coefficients.

Model 1 which displays marginal impacts of climate variables on net farm income per hectare is presented in Table 2. The marginal effects of precipitation and temperature are calculated at mean for each sample. The R^2 value (0.10) shows that climatic variables explain only about 10 percent of this variation in farm value, while F-statistic implies the function to be well behaved.

The findings of Model 1 show that the most estimated coefficients are significant at required levels. The results of marginal impact show that precipitation in the summer and winter has a positive impact on farm value (i.e. increasing returns), while spring and fall precipitation have a negative one (indicating diminishing returns). The square terms reveal that doubling the spring and fall precipitation can lead to a positive impact on farm value, but winter and summer precipitations lead to reduction in the net farm income.

Model 2 estimates the econometric equation incorporating both climate and other socio-economic variables. The R^2 value explains about 11 percent of the variation in net farm revenue per hectare. The test result of F-statistic shows that the function is well-behaved. The findings show that the most estimated coefficients of climate combined with some socio-economic variables are significant, implying the impact of these variables on farm value. For instance, there is a positive impact of spring and summer precipitation but a negative impact of fall precipitation on farm income. A strong positive impact of spring and fall temperature was seen on net farm revenue, but summer temperature had a negative impact. The negative impact of winter temperature on farm value is a bit surprising, due probably to low productive crops such as wheat planted in the winter season.

The productivity of winter crop may be low in the mountain and hilly regions due to the extreme cold temperature. This result needs to be interpreted with caution. The findings of other variables show mixed results. For instance, higher farm output is observed in irrigated farmlands compared to non-irrigated farmlands, but productivity is high in small farms than large farms, showing inverse farm size and productivity relationship. Farmers who obtained credit increased their farm income, showing common problems in low-income countries where credit is one of the constraints for small farmholders. The coefficient of household head's education is significant and negative, implying a negative relationship to net farm income. This result seems to be a bit surprising. Probably educated people preferred to work in the off-farm sector due to low wages and returns in the agricultural sector. Moreover, other variables such as sex and age of household head, distance from input markets, and family size are not significant at any required level, indicating no impact of these variables on farm value at least in this model and data set.

Table 2: Regression equations of the determinants of net farm revenue

Variable	Model 1	Model 2
Winter precipitation	649.77***	-19.53
	(3.63)	(1.56)
Winter precipitation square	-9.63***	
	(3.44)	
Spring precipitation	-259.15**	12.96***
	(2.78)	(4.02)
Spring precipitation square	1.01**	
	(2.73)	
Summer precipitation	101.21***	4.67***
	(4.02)	(4.58)
Summer precipitation square	-0.10***	
	(3.76)	
Fall precipitation	-261.09***	-31.02***
	(3.47)	(4.46)
Fall precipitation square	3.50***	
	(3.56)	
Winter temperature	-1192.1*	-713.4***
	(1.95)	(3.42)
Winter temperature square		
Spring temperature	523.25	891.15***
	(1.48)	(3.83)
Spring temperature square	-17.07	
	(1.40)	
Summer temperature	-943.16***	-468.43**
	(4.01)	(3.19)

Variable	Model 1	Model 2
Summer temperature square		
Fall temperature	1014.55*	26.53
	(1.78)	(0.7)
Fall temperature square		
Farm size		-184.51**
		(2.22)
Ratio of irrigated land in the total land		545.39**
		(2.65)
Distance from input market		-55.34
		(0.15)
Farm credit		516.19**
		(2.20)
Age of household head		4.78
		(0.66)
Sex of household head		17.15
		(0.7)
Education level of household head		-45.92*
		(1.67)
Household family size		51.56
		(0.79)
Constant	-7702.68	-828.87
	(1.19)	(0.78)
R-squared	0.10	0.11
F-statistics	$F_{(13, 634)}$=7.32***	$F_{(16, 639)}$=6.39***
Total observations	**656**	**656**

****, **, and * denote significant at 1, 5 and 10 percent level, respectively; t-statistics are given in the parentheses; some square terms of climate variables omitted in Model 2 due to the problem of multi-collinearity.*

Despite some surprising results about precipitation and temperature, the other findings are in line with the conventional hypothesis of climate change impact on agriculture, implying that rising temperature is likely to reduce farm output. The negative impact of fall and spring precipitation on farm value seems to be reasonable in Nepalese context, because these two seasons are the period of harvesting major crops, such as paddy rice and maize (in fall) and wheat (in spring). If relatively high precipitation occurs during these seasons, there is high probability of damage to the crop output during the harvesting time. On the other hand, high temperature with low precipitation during spring and fall is more likely to be supportive for timely harvesting of cereal crops and reducing the loss of crop output. The positive impact of summer precipitation is also plausible because of heavy dominance of rainfed agriculture in Nepal, indicating that timely precipitation in the summer helps to plant paddy rice and other seasonal crops on time thereby increasing productivity.

Table 3: Marginal impacts of climate change on agriculture in different climatic zones

	Mountain (Alpine zone)	Hills (Temperate zone)	*Tarai* (Semi-tropical zone)
Temperature	19.34	15.55	-211.56
Precipitation	-3.69	1.36*	-24.93**

*** and * denote significant at 5 and 10 percent level, respectively.*

The marginal effects of climate change on agriculture are also evaluated among the ecological belts such as mountain, hills, and *Tarai* (Table 3). The annual average precipitation is likely to increase farm value in the hilly region, but decrease in the *Tarai*. Temperature has a positive impact on farm value in the alpine and temperate zones and a negative one in the sub-tropical zone, but these coefficients are not statistically significant at the required level. However, these findings do indicate some trends as to how the impact of temperature and precipitation on net farm income per hectare varies in different climatic zones.

Table 4: Multivariate linear regression results between first difference of yield and climate conditions (1975 to 2005)

	All cereal crops	Paddy rice	Wheat	Maize	Millet	Barley	Potato
Precipitation	13.02***	9.17***	2.47**	1.30	-0.04	0.13	6.73
	(4.58)	(3.00)	(1.18)	(1.69)	(0.72)	(0.67)	(8.37)
Temperature	-128.67	-69.43	21.05	-74.61	-13.72	8.07	32.08
	(156.83)	(102.78)	(40.44)	(57.86)	(24.69)	(22.88)	(286.49)
Constant	60.23	21.25	30.41**	5.43	-1.23	4.34	237.89
	(54.9)	(35.99)	(14.16)	(20.29)	(8.64)	(8.01)	(100.32)
R^2	0.25	0.27	0.14	0.08	0.02	0.01	0.02

*Note: Std. Errors are in parentheses. *** and ** denote significance at 1 and 5 percent levels, respectively.*

Furthermore, Table 4 presents the result of multivariate linear regression between the first difference of yield and climate conditions (1975 to 2005). R-square shows that more than 25 percent of the variability in crop yields mainly in all cereal crops and paddy rice can be explained by variability in precipitation and temperature between 1975 and 2005. The significant positive sign of precipitation in all cereal crops, paddy rice, and wheat shows that relatively higher precipitation has led to higher yields of these crops, implying that these crops, mainly paddy rice, and wheat are sensitive to climate change. This result seems to be plausible due to the fact that paddy rice has higher requirements of water and is highly sensitive to droughts. In contrast to this, as the temperature coefficients are not significant at any level, the negative signs indicate that increase in temperature may be associated with lower yields. In other words, temperature does not seem to be sensitive with crop yields in these data.

6. Conclusion

Climate change is widely acknowledged as a global concern due to its large effects on human life. Climate change can have multiple impacts on the livelihoods of the people. For instance, impacts of climate variability and change on agricultural sector are projected through changes in land and water regimes, the likely primary conduits of change. Therefore, it is obviously a matter of concern for policymakers and economists due to its impact on the livelihoods.

Using the Ricardian approach, this study attempted to measure the impact of climate change on agriculture in which net farm income is regressed only with climate variables in Model 1 and then with both climate and other socio-economic variables. The explanatory variables include the linear and quadratic terms of precipitation and temperature for the four seasons (winter, spring, summer, and fall), household variables, land, and ratio of irrigated land. The findings show significant impact of climate variables on net farm income per hectare across Nepalese farm households, indicating both positive and negative impact of precipitation and temperature. Net farm income is likely to be increased with low precipitation and high temperature during the fall and spring seasons which are the major harvesting seasons of Nepal. Farmers are likely to increase their revenue with relatively low temperature and enough precipitation during the summer season. Other socio-economic variables have also an impact on net farm income. For instance, net farm income is likely to be high on irrigated farm land combined with obtaining farm credit. But small farms manage better and obtain higher net income per hectare than large farms.

The study also focused on the impact of climate change on agriculture using the Ricardian approach and some interesting results were obtained. As there is a variation in the impact of climate change (i.e. change in precipitation and temperature) on agriculture in different seasons and climatic zones, these variations need to be addressed while formulating adaptation and mitigation strategies of the negative impact of climate change in the country. Since, this study adopted only a Ricardian approach to measure the impact of climate change on agriculture, further study should be carried out using more advanced models, such as agronomic-economic and CGE models.

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