



Impact of Climate Change on Wheat Production in Nepal

Resham Bahadur Thapa-Parajuli^{1,2*} and Niranjan Devkota³

¹Hull University Business School, Hull, UK.

²Central Department of Economics, Tribhuvan University, Nepal.

³Faculty of Humanities and Social Sciences, Tribhuvan University, Nepal.

Author's contribution

This work was carried out in collaboration between both authors. Author RBTP designed the concept, performed the statistical analysis and wrote the first draft of the manuscript. Author ND managed the literature searches, assists to review them, collected the data and commented to manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAEES/2016/22555

Editor(s):

(1) Jamal Alrusheidat, Assistant and Consultant to Director General for Extension Education, Director of Extension Education Department, National Centre for Agricultural Research and Extension (NCARE), Amman, Jordan.

Reviewers:

(1) Sirajul Islam, Bangladesh University of Business and Technology, Dhaka, Bangladesh.

(2) Jie Zhang, Hohai University, China.

Complete Peer review History: <http://sciencedomain.org/review-history/12756>

Short Research Article

Received 9th October 2015
Accepted 9th December 2015
Published 22nd December 2015

ABSTRACT

Following the Ricardian approach, this paper estimates district level fixed effect panel regression on per hectare net wheat revenues with climate variables like precipitation and temperature including other traditional inputs. Both temperature and precipitation coefficients reveal that the climate change caused negative impact on net wheat revenues from wheat production but in a decreasing rate, ceteris paribus. The joint effect of the temperature and precipitation is also significantly negative. Quite trivial that other traditional inputs like population density, manure used, human labour, wages, advanced seed and fertilizer used are positively associated with net revenues. However, per hectare bullock used and tractor price are negatively associated to net revenue. The negative sign reported for the coefficients of quadratic proxy climate change variables but positive for their level form indicate that rising temperature and precipitation initially encourage wheat production in Nepal, but after certain threshold level it start hampering the yield.

*Corresponding author: E-mail: r.b.thapa-parajuli@2014.hull.ac.uk;

Keywords: Precipitation; temperature; wheat yield; Ricardian approach; panel regression.

JEL Classification: Q15; Q51; Q54.

1. INTRODUCTION

Detangling impact of climate change on global wheat production, [1] suggest that a degree centigrade rise in temperature reduces the wheat yield by six percent. Another study done by [2] also claims that the temperature and rainfall volatility had hampered wheat production in Italy. Similarly, study done by [3] reveal that the further increase in temperature would reduce wheat production in South African region. In case of Pakistan, the higher temperature adversely affected wheat productivity as argued by [4]. Likewise, [5] conducted more disaggregated regional level study in Pakistan and found the negative association between wheat productivity and temperature rise in low altitude regions only. However, [6] found positive association between wheat yield and climate change induced CO₂ concentration, in case of Australia. Supporting this argument further, study done by [7] also reveal that temperature rise promoted wheat yields in India through atmospheric CO₂ fertilization channel up to 38^oC threshold. It sounds like the climate change or weather variability affect wheat production at a global level. However, some of the studies on specific geographical areas have established a positive association between climate change and wheat production.

Studies like [6,8] argue that the adverse effect on wheat yield due to temperature rise could be nullified through precipitation enrichment and CO₂ fertilization in the atmosphere. However, the study done by [9] concluded that such atmospheric fertilization can only compensate it scantily. Thus, the further volatility in temperature and rainfall would hamper wheat production as [10] revealed.

Nepal lies near the northern limit of the tropics in the lap of Himalayas and hence it is more vulnerable to climate change. It has wide range of climatic variation like tropical heat with high humidity in summer especially in Terai, the southern plains, and colder dry continental and alpine winter climate through the middle and northern mountainous sections. Such diversity reflects in variations in temperature and precipitation. Thus climate change is a real threat to the lives as it largely affects water resources, agriculture, freshwater habitats, vegetation and forests. At the same time snow melting and

geological processes such as landslide, desertification and floods are regular phenomenon.

Agriculture remains by far the most important sector in the Nepalese economy. Due to the complex topography and climatic variation, the agriculture systems varies as per the geographical location. The main crops cultivated are rice, maize, wheat, millet, mustard, pulses, barley, buckwheat and potato. Wheat is one of the 'policy prioritized' cereal crop, like rice and maize, in Nepal. Wheat is cultivated in 20 percent of the total cultivated land area and contributes 18.8 percent to the total national cereal production. Per capita wheat consumption has increased from 17.4 kg in 1972, at the time of NWRP establishment to 60 kg in 2007 [11].

The delayed monsoon has already been affecting wheat planting and also its yield subsequently. It is worth examining if this has any relation with the changing climate scenario. Most of the discussion about the impact of climate change on wheat production focuses on the temperature regime of the area, which lowers the ripening period. But upland farmers grow wheat crop in unirrigated land, production of which is guided by both temperature as well as the amount of water available. Water requirement of unirrigated wheat is met by the rainfall, which means any change in rainfall time or duration or intensity affects unirrigated wheat yield [12]. Climate change therefore has significant impact in wheat production in countries like Nepal where most of the farming system depends on monsoon and corresponding climate. In this context, it is worth exploring whether the weather volatility has adverse impact in small geographical area with many climatic diversity like Nepal.

The volume of wheat production, cultivated area and productivity increased substantially in Nepal during the last decade. But, surprisingly, about 60 percent variations in wheat productivity was due to weather variability in Nepal [13]. The climate being one of the inevitable inputs in wheat cultivation, weather variability and farm level wheat production, its unpredictability might have some meaningful consequences. There is a dearth of empirical analysis on weather variability and wheat production in Nepal. Thus, this paper aims to untangle this puzzle analysing district level panel information.

2. METHOD OF ANALYSIS AND DATA

Considering land value as the reflection of farmland productivity, [14] suggest an empirical approach to examine the impact of climate vis-à-vis other variables on land value. This approach, commonly known as the Ricardian approach, relates farm level economic data on land value or net revenue with climate variables. Studies like [15] in case of overall Ethiopian Agriculture, [16] in case of Kenyan agricultures, [17] in case of South African Sugarcane and [18] in case of Indian agriculture have used this approach. We also follow this approach to analyse the district level wheat yield revenue, climate variable and other inputs. In order to capture the return from wheat production, we specify the land value (V_L) as:

$$V_L = \int_0^{\infty} \left[\frac{P_i \cdot Q_i^*(K_i, E) - C_i(Q_i^*, \Omega, E_i)}{L_i} \right] e^{-rt} dt \quad (1)$$

$$\Delta W = \int_0^{Q_B} [(P_i Q_i - C_i(Q_i, \Omega, E_B))/L_i] e^{-rt} dQ - \int_0^{Q_A} [(P_i Q_i - C_i(Q_i, \Omega, E_A))/L_i] e^{-rt} dQ \quad (3)$$

If market prices do not change as a result of the change in E, then equation (3) reduces to:

$$\Delta W = [P Q_B - \sum_{i=1}^n C_i(Q_i, \Omega, E_B)] - [P Q_A - \sum_{i=1}^n C_i(Q_i, \Omega, E_A)] \quad (4)$$

Since $P_L L = P_i Q_i - C_i(Q_i^*, \Omega, E)$ holds true under perfect competition, equation (4) becomes:

$$\Delta W = \sum_{i=1}^n (P_{LB} L_{Bi} - P_{LA} L_{Ai}) \quad (5)$$

Where, P_{LA} and L_A are quantities under E_A climatic condition and P_{LB} and L_B under E_B .

The present value of the welfare change is thus:

$$\int_0^{\infty} \Delta W e^{-rt} dt = \sum_{i=1}^n (V_{LB} L_{Bi} - V_{LA} L_{Ai}) \quad (6)$$

Using annual net revenues data, we estimate the extended version of equation (5) as done by [15,19,20]. To see the impacts of exogenous climate change on per hectares net wheat revenues (NR), we regressed it with temperature (*temp*) and precipitation (*preci*) controlling population density (*pop*); seed and fertilizer (*seed_fert*); number of per hectare human labor (*hul*); tractors hours per hectare (*trac*); per hectare bullocks (*bul*); labour wage (*wage*); and per hectare manure (*manu*). The panel regression equation is specified as:

$$\begin{aligned} NR_{ij} = & \beta_0 + \beta_1 temp_{ij} + \beta_2 temp_{ij}^2 + \beta_3 preci_{ij} + \beta_4 preci_{ij}^2 + \beta_5 temp_{ij} * preci_{ij} + \beta_6 pop_{dij} \\ & + \beta_7 seed_fert_{ij} + \beta_8 hul_{ij} + \beta_9 trac_{ij} + \beta_{10} bul_{ij} + \beta_{11} manu_{ij} + \beta_{12} wage_{ij} \\ & + \varepsilon_{ij} ; \varepsilon_{ij} \sim N(0, \sigma^2) \end{aligned} \quad (7)$$

Where P_i is the price and Q_i is the quantity of wheat; K_i is vector of all purchased inputs to produce Q_i ; E_i is vector of environmental factors including climate and soil variables; C_i is cost of production; Ω is a vector of all other factor besides land; L_i is wheat cultivated land in hectares; 'r' is interest rate; and 't' is time. The $(-rt)$ term represents the discounting factor.

The objective function of the farmer who selects K under perfect competition setting to maximize net revenue (π) given farm characteristic is:

$$Max(\pi) = [P_i Q_i - C_i(Q_i, \Omega, E) - P_L L_i] \quad (2)$$

As the environment changes from state A to B, the input availability also changes from E_A to E_B . Thus, the annual net economic welfare (ΔW) changes as:

The 'climate variables' are rolling average for each year that captures the yearly regular response by the farmers and other variables are district level annual data spanning 1993 to 2010. Similar to county level fixed effects specified by [21] while analysing US agriculture and state level fixed effect specified by [18] while analysing Indian Agriculture, we specified district level fixed-effect panel regression in this study. The Hausman specification test (*Annex B*) also supports for the same. The brief descriptive statistics are in *Annex A*. Since the districts are heterogeneous in size and other agricultural activities, we weighted each unit of analysis by total wheat cultivated area expecting to reduce heteroscedasticity problem. The autocorrelation, cross-sectional dependence, heteroscedasticity and others necessary tests are performed, and corrected wherever necessary.

The *temperature and precipitation* related data is from the various periodic from the Department of Hydrology and Meteorology, Government of Nepal. These *Climate variables* represent the wheat cultivation season (November to February) in Terai region of Nepal. The mean temperature and precipitation during this time period prepared by the Department of Hydrology and Meteorology, Government of Nepal is the key variables in this study. They compile these information from several local station. The monthly means were estimated from approximately 25 years of time period and the information is publicly available.

In general, wheat grows in cold temperature. However, it requires different temperatures at different stages of growth and development. The required temperature may slightly vary from one variety to another at its germination. They can grow at minimum 3.5-5.5 degree centigrade to maximum up to 35 degree centigrade, optimum temperature being 20-25 degree centigrade. Beyond this range, wheat seed germination decreases slowly. If temperature is more than 30 degree centigrade during the maturity of the plant, it leads to pre-term maturity resulting yield loss. Winter wheat bears more cold waves and frost compared to spring wheat though. The present rate of annual increase of temperature is 0.06 degree centigrade in Nepal, though the trends of temperature rise is not uniform.

The wheat is cultivated in the region where annual precipitation occurs from 25 to 175 cm, though 75 per cent of wheat cultivated area in Nepal falls where the annual rainfall precipitation

occurs between 37.5 mm to 87.5 mm according to Nepal Agriculture Research Council. Region with 62.54 to 87 mm rainfall are most suitable for wheat cultivation and out of this 10-15 mm rainfall is required when crop is in the field. Rainfall and snowfall at the time of maturity causes severe loss to wheat crop adversely affecting the yield and seed quality. Due to the topographical differences within short north-south span of the country, Nepal has wide variety of climatic condition. About 70 to 90 percent of the rainfall occurs during the summer monsoon months (June to September) in Nepal and the rest of the months are almost dry.

The data related with fertilizer, improved seeds, use of manure and price of agricultural inputs comes from the Department of Agriculture, Government of Nepal. The *Socio-economic variables* included in the estimation are district level population density, use of fertilizer, use of improved seeds, use of manure, total wheat cultivated area, total production and the price of agricultural inputs. The census information produced by Central Bureau of Statistic in every ten years is the base for the *population density*. The population growth rate from 1992/93 to 2000/01 and 2000/01 to 2010/11 gives the district level growth rate, which is sufficient to estimate the district level annual population. We prepared the population density variable by dividing the area of the respective district. Total estimated wheat cultivated area and volume of wheat produced in KG for all sample districts of 20 Terai districts of Nepal during 1992/93 to 2013/14 from various publications of the Ministry of Agriculture & Co-operatives and the Central Bureau of Statistics (CBS).

The Department of Agriculture, Market Research and Statistical Management Program, Government of Nepal publishes the "Cash or Production & Marketing Margin of Cereal, Cash, Vegetable & Spices Crops, Nepal" annually. We compiled the *per hectare fertilizer* use at district level from this source. Seeds is another important factor of production for our analysis, therefore we compiled total *improved seeds* used from the same source. The concerned officers in the department revealed that in case of wheat seeds inputs are generally improved seeds. Optimum planting date for Terai is found to be the middle of November. However, wheat sowing in Terai can be delayed up to the second week of December without significant reduction in the yield and wheat seed sown beyond these dates result the yield reduction of 30 to 50 kg/day/ha. In

previous years there was general recommendation for the seed rate of 100 kg/ha. Recent experiments have shown that additional seeds of 25 to 50 kg/ha is required under late sown and under farmers' broadcast system. Similarly, we compiled the per hectare for *human labor, bullock labor, tractor used and Manure and Price of Agricultural Inputs* at district level from the same sources.

3. IMPACT OF CLIMATE CHANGE ON WHEAT PRODUCTION IN NEPAL

The summary of the regression results is in Table 3.1. It reveals that, the temperature and net revenue from wheat are positively associated, but at a decreasing rate. It signifies that as temperature increases, the wheat yield in Nepal increases as well, other things remaining the same. Since wheat is cultivated in winter or cold session in Nepal, the temperature rise might have promoted wheat yield. But, as the

temperature increases beyond certain level, it hampers the yield as the coefficient of the quadratic term for temperature suggests. If an average temperature was above 21°C, the temperature rise would start damaging wheat yield as found by [7] in case of India. The coefficient indicates that one unit increase in temperature helps to produce about NRS 5,643 worth more net revenues per hectare but if the temperature is beyond 19°C, the revenue starts falling significantly. It is similar to the argument given by [22,23] that the minimum optimal temperature threshold for wheat production in Nepal is 20°C. According to [24], the annual increase of temperature in Nepal is 0.06°C. It is recorded at 0.04°C in wheat cultivating area with 18.30°C annual average maximum temperature during wheat cultivation period. Thus, it can be argued that the climate change will support wheat production in Nepal up to certain threshold only, analogous to the finding by [7] in case of India.

Table 3.1. Fixed effect panel regression results

Dependent variable (→)	Net revenue from wheat yield	
Independent Variables (↓)	(1)	(2)
Temperature	5,643** (2,834)	-
Temperature squared	-153.9** (72.23)	-
Precipitation	161.1* (90.45)	-
Precipitation squared	-6.222*** (2.017)	-
Precipitation * Temperature	-	-4.310** (2.073)
Population density	186.1*** (16.00)	179.4*** (16.14)
Manure per hectare	0.0447 (0.0353)	0.0279 (0.0355)
Human labour per hectare	90.25** (40.23)	87.80** (40.81)
Bullock per hectare	-318.6*** (63.12)	-324.2*** (63.73)
Tractor hour per hectare	-478.1** (207.4)	-540.1** (209.8)
Wage of human labour per hectare	-0.217*** (0.0829)	-0.176** (0.0834)
Fertilizer and Seed per hectare	-0.0151 (0.0780)	-0.0732 (0.0778)
Constant	-100,835*** (29,668)	-44,340*** (7,876)
Observations	440	440
R-squared	0.716	0.705
Number of district	20	20

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Similar to the temperature, there is a positive relationship between precipitation and net revenues from wheat but is insignificant. It indicates that precipitation alone is not the primary determinant and other environmental factors as well as traditional inputs, are important to enhance wheat production. Nevertheless, the negative and significantly negative coefficient of the quadratic term of the precipitation indicates that the precipitation and the net revenue are positively associated but in decreasing rate. After certain threshold level, the association becomes opposite. The precipitation data ranges from zero to sixty five mm with median precipitation 7.8 mm (*Detail in Annex A*). The quadratic coefficient indicates that if the precipitation level is above average (12.95 in proper), an extra unit of precipitation damages the wheat yield. It causes negative impact in the net revenues, *ceteris paribus*. In this context, a past study by [8] argue that increased precipitation level supports wheat yield but [6] believe opposite.

The precipitation and temperature interaction variable is regressed controlling other variable and the results are reported in the Table 3.1. The negative and statistically significant coefficient suggests that the joint effect of the temperature and precipitation damages the wheat yield significantly. It can be argued that if the temperature and precipitation both increases, the joint climatic impact in wheat yield would be significantly negative in Nepal. Thus, it can be argued that the climate change although initially promotes wheat production in Nepal, but after certain threshold level, it might not.

The statistically significant and positive population density coefficient indicates that higher the population, higher will be the net revenues from wheat production. It might have worked through input market and output market efficiency channel. It might be the case that if more people, more workers available in cheaper price so that the productivity increases. At the same time, more density is proxy to the higher market or aggregate demand for the wheat produced which induced wheat cultivation. The positive though insignificant coefficient for per hectare manure suggests that the wheat cultivation is less manure demanding than other crops. But, positive coefficient suggest for higher the manure used, the higher will be the net revenues from wheat in Terai, Nepal. It is quite natural that the traditional compost is the best for the wheat. The human labour coefficient is positive but insignificant indicating labour as a

necessary but not sufficient input for optimum wheat production. More traditional technology like ploughing by Bullock for wheat farming has negative role on net revenue though the coefficient is insignificant. It might be the indication for modern means of ploughing which are effective than the scarce and costly traditional ones that farmers are using.

Tractor, means of modern cultivation, is significant to bring change in net revenues. However, if the price of tractor goes up, their use will decrease and farmers will resort to the same traditional patterns. Interestingly, when wages increase, per hectare net revenues also increase significantly. It indicates for the scarcity of the human labour in Nepal due to outmigration and abundance of traditional farming practices within the household level. As someone starts the commercial wheat farming by hiring labour formally with other inputs, the net revenues generated overweight the average wage paid, *ceteris paribus*. Advanced seed and fertilized are important input for wheat cultivation like any other agriculture. Generally, farmers buy these two inputs together. The coefficient indicates that one extra rupee invested in seed and fertilizer brings the revenue less by some positive amount though insignificant. It suggests for imperfect input market for the agriculture sector in Nepal.

About 71 percent variation in net revenues is due to the variation in the explanatory as the coefficient of determination (R^2) indicates. No cross sectional dependency is detected using Pesaran test. The Wooldridge autocorrelation test signals for presence of autocorrelation and Wald test signals for the presence of Heteroscedasticity. The panel unit root test indicates that the variables we used are unit root free variables. To overcome the autocorrelation and heteroscedasticity problem, we estimated generalized least square regression (see *Appendix C*). Pedroni test statistics for panel co-integration suggest that the variables are almost co-integrated, the summary of the test is mentioned in *Appendix D*.

4. CONCLUSIONS

The temperature and wheat net revenues are positively associated, but at a decreasing rate. As temperature increases, the wheat yield in Nepal increases as well, other things remaining the same. However, temperature rise will support wheat production in Nepal up to certain threshold level only. Similarly, the precipitation and net

revenues from wheat are also positively associated but not very significantly. Moreover, the association is in a decreasing rate. Nevertheless, the joint effect of the temperature and precipitation damages the wheat yield significantly. If temperature and precipitation both increase, the joint climatic impact in wheat yield would be significantly negative in Nepal. Thus, it can be argued that the climate change initially promotes wheat production in Nepal, but after certain threshold level it might not.

Other traditional inputs like population density, manure used, human labour, wages, advanced seed and fertilizer used are positively associated with net revenues. However, ploughing by bullock for wheat farming and tractor price are negatively associated to the net revenue from wheat yield in Nepal.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Keshab Bhattarai for his comments and suggestions in the preliminary draft of this paper. We express our gratitude to thank Elvis Hernández for critical comments during the designing phase and Rachana Upadhyaya for painstaking proof reading. We would like to thank two anonymous referees and editors for insightful comments and suggestions. Supplementary information and the data used are available upon request.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Asseng S, Ewert F, Martre P, Rotter RP, Lobell DB, Cammarano D, et al. Rising temperatures reduce global wheat production. *Nature Clim. Change*. 2015;5(2):143-147.
2. Falcucci A, Maiorano L, Boitani L. Changes in land-use/land-cover patterns in Italy and their implications for biodiversity conservation. *Landscape Ecology*. 2007;22(4):617-631.
3. Gbetibouo GA, Hassan R. Measuring the economic impact of climate change on major South African field crops: A Ricardian approach. *Global and Planetary Change*. 2005;47(2):143-152.
4. Janjua PZ, Samad G, Khan NU, Nasir M. Impact of Climate Change on Wheat Production: A case study of Pakistan. *The Pakistan Development Review*. 2010; 12(1)1:799-822.
5. Hussain SS, Mudasser M. Prospects for wheat production under changing climate in mountain areas of Pakistan: An econometric analysis. *Agricultural Systems*. 2007;94(2): pp. 494-501.
6. Luo Q, Williams MA, Bellotti W, Bryan B. Quantitative and visual assessments of climate change impacts on South Australian wheat production. *Agricultural Systems*. 2003;77(3):173-186.
7. Attri S, Rathore L. Simulation of impact of projected climate change on wheat in India. *International Journal of Climatology*. 2003;23(6):693-705.
8. Wolfe DW, Schwartz MD, Lakso AN, Otsuki Y, Pool RM, Shaulis NJ. Climate change and shifts in spring phenology of three horticultural woody perennials in northeastern USA. *International Journal of Biometeorology*. 2005;49(5):303-309.
9. Anwar MR, O'Leary G, McNeil D, Hossain H, Nelson R. Climate change impact on rainfed wheat in south-eastern Australia. *Field Crops Research*. 2007;104(1):139-47.
10. Cerri CE, Sparovek G, Bernoux M, Easterling WE, Melillo JM, Cerri CC. Tropical agriculture and global warming: Impacts and mitigation options. *Scientia Agricola*. 2007;64(1):83-99.
11. Thakur NS, Paudel MN, Gauchan D, Shrestha B. Measuring returns from improved rice, maize and wheat research in Nepal. *Nepal Agriculture Research Journal*. 2014;8:103-12.
12. Bhatta GD, Aggarwal PK. Coping with weather adversity and adaptation to climatic variability: A cross-country study of smallholder farmers in South Asia. *Climate and Development*. 2015;1-3. DOI: 10.1080/17565529.2015.1016883
13. Nayava JL, Singh R, Bhatta, MR. Impact of climate, climate change and modern technology on wheat production in Nepal: A case study at Bhairahawa. *Journal of Hydrology and Meteorology*. 2009;6(1):1-14.
14. Mendelsohn R, Nordhaus WD, Shaw D. The impact of global warming on agriculture: A Ricardian analysis. *The American economic review*. 1994; 84(4):753-71.
15. Gebreegziabher Z, Mekonnen A, Deribe R, Abera S, Kassahun MM. Crop-livestock

- inter-linkages and climate change implications for Ethiopia's agriculture: A Ricardian Approach; 2013.
16. Kabubo-Mariara J, Karanja FK. The economic impact of climate change on Kenyan crop agriculture: A ricardian approach. *Global and Planetary Change*. 2007;57(3):319-330.
 17. Deressa TT. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. *World Bank Policy Research Working Paper*. 2007;1(4342).
 18. Kumar KK. Climate sensitivity of Indian agriculture: Do Spatial effects matter? *South Asian Network for Development and Environmental Economics*. 2009;45(9).
 19. Dinar A. Measuring the impact of climate change on Indian agriculture. *World Bank Publications*; 1998.
 20. Kumar KK, Parikh J. Climate change impacts on Indian agriculture: The ricardian approach. *Measuring the Impact of Climate Change on Indian agriculture*. 1998;141-184.
 21. Deschenes O, Greenstone M. The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. *The American Economic Review*. 2007;97(1): 354-85.
 22. Bhujel R, Jha R, Yadav B. An empirical analysis of resource productivity of wheat in Eastern Terai Region of Nepal. *Nepal Agriculture Research Journal*. 2009;9:182-191.
 23. Devkota N. Climate change and wheat production in Nepal. Unpublished, MPhil Thesis, Central Department of Economics, Tribhuvan University, Kathmandu; 2013.
 24. Shrestha AB, Wake CP, Mayewski PA, Dibb JE. Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971-94. *Journal of climate*. 1999;12(9):2775-2786.

Appendix A: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
district	440	10.5	5.772845	1	20
year	440	2003.5	6.351511	1993	2014
n_revenue	440	24212.99	15110.47	400.51	64695.56
preci	440	11.38584	11.90006	-.43	64.9
pre_sq	440	270.9271	520.411	0	4212.01
temp	440	18.22693	1.612997	12.1	26.4
temp_sq	440	334.8169	61.5078	146.41	696.96
pre_temp	440	203.288	210.9269	-6.4285	1148.73
popln_den	440	384.7586	156.0365	124.77	694.02
manure_hec	440	30587.71	14679.36	3500	104221.3
human_l_hec	440	108.2523	10.7255	77	130
bullock_hec	440	14.04545	11.89831	0	43
tractor_hec	440	4.480682	2.754183	0	13
f_s	440	14968.6	6057.095	8060	62228
p_humanlabor	440	10601.71	8107.095	2430	38500

Appendix B: Hausman Test for Fixed Effect

```
. xtregn_revenuepreci_pre_sq temp
temp_sqpre_temp popln_den manure_hech human_l_hecbullock_hectractor_hecp_humanlaborf_s, fe

Fixed-effects (within) regression
Group variable: district

Number of obs   =   360
Number of groups =   20

R-sq: within = 0.8494
      between = 0.0480
      overall  = 0.1640

Obs per group: min =   18
                avg  =  18.0
                max  =   18

corr(u_i, Xb) = -0.8551

F(12,328)      =  154.14
Prob> F        =  0.0000

-----+-----
n_revenue |   Coef.   Std. Err.   t    P>|t|   [95% Conf. Interval]
-----+-----
  preci |   -84.9092   351.2157   -0.24  0.809   -775.8288   606.0104
  pre_sq |   -4.129809   1.493781   -2.76  0.006   -7.068409   -1.19121
   temp |   8652.686   2623.735    3.30  0.001   3491.215   13814.16
temp_sq |   -215.3559   64.0424   -3.36  0.001   -341.3415   -89.37017
pre_temp |    9.026758   18.38951    0.49  0.624   -27.14951   45.20303
popln_den |   142.9818   14.64646    9.76  0.000   114.1689   171.7947
manure_hec |    1.362966    .537247    2.54  0.012    .306081   2.41985
human_l_hec |   17.95916   34.55132    0.52  0.604   -50.01098   85.9293
bullock_hec |   -56.44384   56.03452   -1.01  0.315   -166.6762   53.78854
tractor_hec |  -1120.388   155.2621   -7.22  0.000   -1425.823   -814.9526
p_humanlabor |   329.3814   58.9499    5.59  0.000   213.4138   445.349
f_s |    2.384321    .4445116    5.36  0.000    1.509867   3.258774
   _cons |  -145503.1   27646.24   -5.26  0.000  -199889.5  -91116.82

-----+-----
sigma_u | 22841.213
sigma_e | 5469.3652
   rho | .94577219 (fraction of variance due to u_i)

-----+-----
F test that all u_i=0:   F(19, 328) =  11.62      Prob> F = 0.0000

. estimates store fixed

. xtregn_revenuepreci_pre_sq temp
temp_sqpre_temp popln_den manure_hech human_l_hecbullock_hectractor_hecp_humanlaborf_s, re

Random-effects GLS regression
Group variable: district

Number of obs   =   360
Number of groups =   20

R-sq: within = 0.8059
      between = 0.0005
      overall  = 0.7471

Obs per group: min =   18
                avg  =  18.0
                max  =   18

Wald chi2(12)      =  1331.59
Prob > chi2        =  0.0000

corr(u_i, X) = 0 (assumed)

-----+-----
n_revenue |   Coef.   Std. Err.   z    P>|z|   [95% Conf. Interval]
```

```

preci | 334.9989 397.4231 0.84 0.399 -443.936 1113.934
pre_sq | -4.272225 1.703212 -2.51 0.012 -7.610459 -.9339906
temp | 5969.376 2874.481 2.08 0.038 335.4959 11603.26
temp_sq | -150.5612 70.3799 -2.14 0.032 -288.5032 -12.61912
pre_temp | -14.75355 20.7848 -0.71 0.478 -55.49102 25.98391
popln_den | 4.087303 5.401135 0.76 0.449 -6.498727 14.67333
manure_hec | .9143847 .6084557 1.50 0.133 -.2781665 2.106936
human_l_hec | 77.91307 37.99867 2.05 0.040 3.437041 152.3891
bullock_hec | -366.8832 54.52007 -6.73 0.000 -473.7406 -260.0258
tractor_hec | -1615.167 167.9277 -9.62 0.000 -1944.299 -1286.034
p_humanlabor | 333.3264 67.15762 4.96 0.000 201.6998 464.9529
f_s | 4.311713 .4570843 9.43 0.000 3.415844 5.207582
_cons | -73703.23 29533.36 -2.50 0.013 -131587.6 -15818.9
-----+-----
sigma_u | 2541.0059
sigma_e | 5469.3652
rho | .17752523 (fraction of variance due to u_i)
-----+-----

. hausman fixed ., sigmamore

Note: the rank of the differenced variance matrix (9) does not equal the number of coefficients
being tested (12); be sure this is what you expect, or there may be problems
computing the test. Examine the output of your estimators for anything unexpected and possibly
consider scaling your variables so that the coefficients are on a similar
scale.

---- Coefficients ----
| (b) (B) (b-B) sqrt(diag(V_b-V_B))
| fixed . Difference S.E.
-----+-----
preci | -84.9092 334.9989 -419.9081 63.80529
pre_sq | -4.129809 -4.272225 .1424156 .1727872
temp | 8652.686 5969.376 2683.311 882.6468
temp_sq | -215.3559 -150.5612 -64.79467 20.8244
pre_temp | 9.026758 -14.75355 23.78031 3.487651
popln_den | 142.9818 4.087303 138.8945 15.89294
manure_hec | 1.362966 .9143847 .4485808 .0942647
human_l_hec | 17.95916 77.91307 -59.95391 11.13905
bullock_hec | -56.44384 -366.8832 310.4393 33.93511
tractor_hec | -1120.388 -1615.167 494.779 58.84288
p_humanlabor | 329.3814 333.3264 -3.944976 7.360771
f_s | 2.384321 4.311713 -1.927392 .2249387
-----+-----

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(9) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 89.06
Prob>chi2 = 0.0000
(V_b-V_B is not positive definite)

```

Appendix C: Pre and Post Estimation Tests

Heteroskedasticity Test	
. xttest3	
Modified Wald test for groupwise heteroskedasticity in fixed effect regression model	
H0: $\sigma(i)^2 = \sigma^2$ for all i	
chi2 (20) = 233.03 Prob>chi2 = 0.0000	
Panel Unit root test	
. xtunitrootllcn_revenue if district, demean lags(aic 5) kernel(bartlettwest)	
Levin-Lin-Chu unit-root test for n_revenue	

Ho: Panels contain unit roots	Number of panels = 20
Ha: Panels are stationary	Number of periods = 18
AR parameter: Common	Asymptotics: N/T -> 0
Panel means: Included	
Time trend: Not included	Cross-sectional means removed
ADF regressions: 0.60 lags average (chosen by AIC)	
LR variance: Bartlett kernel, 4.40 lags average (chosen by Newey-West)	

	Statistic p-value

Unadjusted t	-5.8025
Adjusted t*	0.4329 0.6675

Panel Autocorrelation	
Wooldridge test for autocorrelation in panel data and found the presence of first-order autocorrelation test: $F(1, 19) = 21.303$; Prob> F = 0.0002	
Cross Section Dependence	

xtcsd, pesaran show	
Pesaran's test of cross sectional independence = 11.474, Pr = 0.0000	
Correction of Autocorrelation and Heteroskedasticity	
. xtglsln_revenueprecipre_sq temp temp_sqpre_temppopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlaborf_s	
Cross-sectional time-series FGLS regression	
Coefficients: generalized least squares	
Panels: homoskedastic	
Correlation: no autocorrelation	
Estimated covariances = 1	Number of obs = 360

Estimated autocorrelations =	0	Number of groups =	20
Estimated coefficients =	13	Time periods =	18
Log likelihood =	-3685.208	Wald chi2(12) =	1155.00
		Prob> chi2 =	0.0000

n_revenue	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
preci	475.2884	418.2541	1.14	0.256	-344.4745 1295.051
pre_sq	-4.606559	1.801752	-2.56	0.011	-8.137928 -1.075189
temp	5762.312	2766.743	2.08	0.037	339.5948 11185.03
temp_sq	-151.8942	68.14121	-2.23	0.026	-285.4485 -18.33993
pre_temp	-20.82191	21.89278	-0.95	0.342	-63.73098 22.08715
popln_den	-3.195161	3.236932	-0.99	0.324	-9.539432 3.149109
manure_hec	.3688337	.6318778	0.58	0.559	-.8696241 1.607292
human_l_hec	43.37647	38.44246	1.13	0.259	-31.96937 118.7223
bullock_hec	-454.4937	55.56617	-8.18	0.000	-563.4014 -345.586
tractor_hec	-1676.273	175.1353	-9.57	0.000	-2019.532 -1333.014
p_humanlabor	281.9043	71.10775	3.96	0.000	142.5356 421.2729
f_s	4.324616	.4823708	8.97	0.000	3.379186 5.270045
_cons	-57580.59	28292.03	-2.04	0.042	-113031.9 -2129.237

Appendix D: Pedroni Test Results for Panel Co-integration

Pedroni panel co-integration test:
 Pedroni's PDOLS (Group mean average):
 No. of Panel units: 20 Lags and leads: 2
 Number of obs: 340 Avg obs. per unit: 17
 Data has been time-demeaned.

Variables	Beta	t-stat
preci_td	-375.8	-7.112
pre_sq_td	2.062	6.156
temp_td	44854	16.89
temp_sq_td	-1032	-14.39
pre_temp_td	-42.4	-12.06
popln_den_td	292.9	15.7
manure_hec_td	1.019	9.875
human_l_hec_td	-401.1	-6.622
bullock_hec_td	3214	16.13
tractor_hec_td	-3133	-8.866

Appendix E: STATA Do File

```
log using "E:\paper_1.smcl"
import excel "E:\new_data.xls", sheet("Sheet1") firstrow
xtset district year
sum
xtsum
sum preci temp, detail
xtreg revenueprecipre_sq temp
temp_sqpopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlaborf_s, fe
outreg2 using E:\output.doc
xtreg revenuepre_temppopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlab
orf_s, fe
outreg2 using E:\output.doc, append
xtreg revenueprecipre_sq temp
temp_sqpopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlaborf_s, fe
estimates store fixed
xtreg revenueprecipre_sq temp
temp_sqpopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlaborf_s, re
hausman fixed ., sigmamore
xtreg revenuepre_temppopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlab
orf_s, fe
estimates store fixed
xtreg revenuepre_temppopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlab
orf_s, re
hausman fixed ., sigmamore
xtreg revenueprecipre_sq temp
temp_sqpopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlaborf_s, fe
xttest3
xtreg revenuepre_temppopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlab
orf_s, fe
xttest3
xtunitrootllcn_revenue if district, demean lags(aic 5) kernel(bartlettwest)
xtcsd, pesaran show
xtglsn_revenueprecipre_sq temp
temp_sqpre_temppopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_humanlaborf_s ,
igls panels (heteroskedastic)
estimates store hetero
xtglsn_revenuepre_temppre_temppopln_denmanure_hechuman_l_hecbullock_hectractor_hecp_h
umanlaborf_s , igls panels (heteroskedastic)
estimates store hetero
xtpedronin_revenueprecipre_sq , full notest
xtpedronin_revenue temp temp_sq, full notest
xtpedronin_revenuepre_temppopln_den , full notest
xtpedronin_revenueanure_hechuman_l_hec , full notest
xtpedronin_revenuebullock_hectractor_hec, full notest
log close
```

© 2016 Thapa-Parajuli and Devkota; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
<http://sciencedomain.org/review-history/12756>