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Research Article

Impact of climate change on rice production: an empirical study in Kaski and Nawalparasi, Nepal

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ABSTRACT

This study explores the relationship between climate variables to rice production in Kaski and Nawalparasi district of Nepal. The study was conducted in the year 2016. This study captured the time series data ranging from 1995 to 2014 on rice production, temperature and rainfall of two different districts and analyzed through panel data regression. Regarding primary data collection, a total of 120 sampled households were surveyed by using simple random sampling to understand the perception of farmers to change in climatic parameters using a semi-structured pre-tested questionnaire and Focus Group Discussions. The secondary information was collected from the Ministry of Agriculture and Livestock Development, Department of Hydrology and Meteorology and Centre Bureau of Statistics. The regression model revealed that seasonal rainfall had a linear relation on rice production ($p<0.05$). Respondents from both districts perceived that temperature, rainfall and hailstone had increased or varied than before. The major problems faced by the farmers of the study area due to climate change were prioritized as drought, flood hailstone, extreme hot and extreme cold. This necessitates the promotion and use of climate-smart technologies for better rice adaptation to climate change.

Keywords: climate change, panel data, perception, rice.

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INTRODUCTION

Climate change is a long-term change in climatic variables. The term often refers to rise in global temperature, especially associated with persistent anthropogenic activities which indeed alters the atmospheric gas composition (IPCC, 2014a). Intergovernmental Panel on Climate change (IPCC) defines climate change is the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for

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an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or because of human activity.

Agriculture sub-sector is a prime concern of human being and agricultural practices heavily depends on natural resources, particularly water, soils, and forests. It is particularly vulnerable to extreme weather events such as severe warming, extreme rainfall, drought, floods, cold waves, etc. which ultimately decrease the productivity of crops (NAPA, 2010). IPCC predicted that by the year 2100 the increase in global average surface temperature will be between 1.8 and 4.0^0C which results in approximately 20-30 percent of plant and animal species expected to be at risk of extinction (IPCC, 2014b). The impact of climate change in South Asia including Nepal is expected to be higher than the average for the entire globe due to its fragile mountainous environments. This could reduce crop production and productivity further (Joshi *et al.,* 2011).

Rice (*Oryza sativa* L.) is a major staple food crop in Nepal.Rice is found to be grown in the three distinct major agro-ecological zones, which are: Terai and inner Terai (60-900 masl), Mid hills (900-1,500 masl) and Mountains/High hills (1,500 -3,050 masl) (Subedi et al., 2020).It contributes 15.35% in Agricultural Gross Domestic Product (MoALD, 2019). This crop provides more than 40% of the total calorie requirement of Nepalese people (Basnet, 2015) underpinning the important role of rice in country food and nutrition security. Nepal Agricultural Research Council (NARC) has been playing a significant role to improve the rice productivity in the country. The current production is not sufficient to meet the demand of growing population and ensure food security in the country (Shrestha *et al*., 2020).Nonetheless, rice cultivation is threatened by change in climatic variables as entire agricultural production is sensitive to natural disasters such as droughts, floods, landslides, etc. In recent years, changes in the precipitation pattern rise in temperature, cold waves, increasing dry spells and occurrences of prolonged drought, etc. are adversely affecting almost all areas of Nepal. The national average annual temperature rise is 0.06°c but it is more in the mountainous area than plain area with an increase of 0.08°c (MoE, 2012). Further, rice cultivation needs a great quantity of water (3,000 liters of water is required to produce 1 kg of rice) making this crop sensitive to climatic stress for example drought in particular (Basnet, 2009).

Kaski district is affected by the excess rainfall including hailstorms and storms during the crop growing and harvesting periods, resulting in a decline of the summer crop production especially paddy, maize and millets (WFP,2013). Excess rainfalls with hailstorms have also damaged ripening paddy and millet crops in 15 VDCs of Kaski district resulting 10 to 50 percent food crop loss in various VDCs including some areas of Pokhara sub-metropolitan city. However, the production loss due to hailstorms was about 1 percent in aggregate (WFP, 2012). Similarly, Nawalparasi district also facing problems like hailstone, wind, drought during rice growing season resulting crucial loss (WFP, 2013). By realizing this fact and to capture climate change impact on paddy crop in two different ecological zone, Kaski (Midhill) and Nawalparasi (Terai) district were selected for the study. How paddy crop is being affected by emerging threat of climate change and to find out major climatic variables impacted on paddy production along with farmer's perception due to climate change were the objectives of this study.

At the National level, the Government of Nepal has announced the implementation of the National Climate change policy 2011. Further, the climate change issue has been given prime importance at each level of periodic plan, Agriculture Development strategy, South Asian Association for regional cooperation (SAARC) summit and other national - international

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programs. Further, the government has given high priority to climate change, particularly adopting suitable local climate change adaptation practices for enhancing sustainable agriculture and to maintain agriculture production and productivity to meet present needs that could be seen in recently endorsed twenty-year plan (ADS, 2015) and interim plan. However, there are negligible researches that focus on the impact of climate change on cereal production in particularly focusing on rice. Therefore, the main objective of this study was to determine the effect of climate variables on rice production, farmer's perception on climatic parameters and ranking of climatic hazards based on respondent's responses.

MATERIALS AND METHODS

This study was conducted in two locations representing the terai and mid-hill of Nepal. Kaski district from mid-hill and Nawalparasi district from terai were selected purposively. Lumle and PumdiBhumdi VDCs from Kaski district and Agyauli and Kolhuwa VDCs from Nawalparasi district were purposively selected for the study in 2016. From each VDC, 30 samples and in total 120 households were selected using a simple random sampling technique. Semi-structured pretested questionnaires were used to collect primary data regarding farmers' perceived changes in climatic parameters. The secondary data for the analysis was based on the panel data on rice production of both districts ranging from 1995 to 2014 was collected from the Ministry of Agriculture and Livestock Development. Similarly, the same period panel data regarding temperature and rainfall were collected from the Department of Hydrology and Meteorology.

METHOD OF DATA ANALYSIS

Collected data were fed into a computer and data entry was done at MS EXCEL. Further analysis was done by using Statistical Package for Social Sciences (SPSS) Version 16, STATA and MS EXCEL. Farmer's perception regarding the change in climatic parameters was analyzed on MS EXCEL and presented on bar-graph. The other analysis framework was presented below.

Analytical Framework

The empirical strategy of the study is to estimate a functional relationship between rice production and climatic variables using panel data regression (Equation I).

$Y_{it} = \beta_0 + \beta_1 .PPT_{it} + \beta_2 TMP_{it} + \beta_3 DD$ ....Equation I

Where,

Y_{it}= production of rice crop in Metric tons in t years

PPT_{it}= Rainfall measured in millimeters for 't' years

TMP_{it}= Temperature measured in degree Celsius for 't' years

DD = District Dummy (1=Kaski, 0=Nawalparasi)

The panel data model (Equation I) uses minimum temperature, maximum temperature, seasonal total rainfall and total rainfall and district dummy as fixed variables. We used time-series data (1995-2014) on rice production of Kaski and Nawalparasi districts and set a statistical relation to total rainfall and seasonal rainfall as well as average maximum and minimum temperature. The variables and expected signs according to the nature of the used variables were depicted in Table 1.

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Table 1: Description and expected signs explanatory variables.

Variables	Description	Expected sign
Production	Production in Metric tons in Kaski and Nawalparasi	+
Minimum temperature	Average temperature from June to September in degree Celsious.	+/-
Maximum temperature	Average temperature from June to September in degree Celsius.	+/-
Total rainfall	Total rainfall in a year in millilitre.	+/-
Seasonal total rainfall	Seasonal total(June to September) in milliliter	+/-
District Dummy	Kaski and Nawalparasi (if 1= Kaski, 0=Nawalparasi)	+/-

Scaling of Major Climatic Hazards

Scaling techniques, which provide the direction and extremity attitude of the respondent towards any proposition, was used to construct an index. The major climatic hazards being faced by the rice producer were analyzed by using four points scaling technique. The points consist of strongly agree, somewhat agree, agree least agree and disagree using score of 1.00, 0.75, 0.50, 0.25 and 0, respectively (Figure 1). The formula as depicted in Equation II was used to find the index for severity of climatic hazards. Subedi *et al.* (2019) used the similar formula to calculate value of intensity of problems in potato produciton and Shrestha and Shrestha (2017) in maize seed production.

$$I_{prob} = \sum \frac{S_i f_i}{N} \text{ ....Equation II}$$

Where,

I_{prob} = Index value for intensity of problem

$\sum$ = Summation

S_i = Scale value of i^{th} intensity,

f_i = Frequency of i^{th} response

N = Total number of respondents

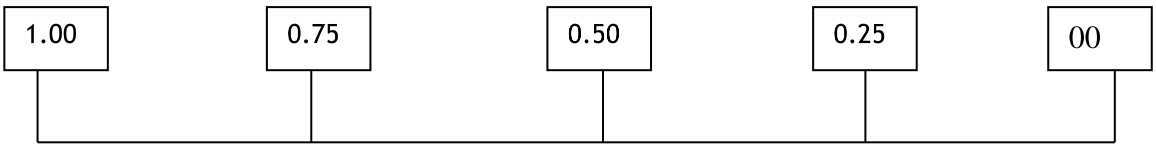

Figure 1: Scale value for prioritization

RESULTS AND DISCUSSION

Effect of Climate Variables on Rice Production

The analysis showed a mixed result. Among the explanatory variables used in the present study, we found multicollinearity between total rainfall and total seasonal rainfall (VIF=13.29), therefore total rainfall was removed from the model and rechecked the model assumptions and found valid. The result revealed that total seasonal rainfall affected rice production significantly ($p<0.05$). Although the test result was statistically insignificant, maximum temperature, district dummy has negatively associated with Paddy Production

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(Table 2). Unlike maximum temperature, the minimum temperature is positively associated with paddy production in both districts although it is also statistically insignificant.

Table 2. Result of panel data regression

Variables	Coefficient	Standard error	p> t
Maximum temperature	-9146.91	8606.86	.30
Minimum temperature	6231.21	11380.73	.59
Seasonal total rainfall*	77.90	30.62	.02
District dummy	-141354	114812.4	.23
Constant	324674.2	379845.7	.40

* Significance at p= 5%

Prob>f	0.000
R-squared	0.88
Adjusted R-squared	0.86

The result showed that Seasonal rainfall has positive impacts on rice production. One millimeter increase in seasonal rainfall, the rice production will be increased by 77.90 Metric tons (Table 2). Our result is similar to Sapkota *et al.* (2011), Basak *et al. (*2010) and Karn (2014). All these studies showed that rice production is directly associated with water sufficiency. At the nursery stage and growing period of the rice plant, deficit or varying rainfall found to be having a strong negative effect on its yield. In Agriculture, it is believed that the changes in temperature and precipitation directly result in land and water regime changes resulting in changes in agricultural productivity than potential (World Bank, 2003). However, the present study could not show the significant linear relation between temperature and rice production. This could be due to fact that the change in temperature over the study period is very minimum and only 20 years of data was used for regression. Also, there are other major productions influencing factors, for example, timely availability of fertilizers, grown varieties etc.

Perception of Farmers on Climatic Parameter

Respondents from both districts perceived that temperature had increased than before. Similarly, only 15 and 13.3 percentages of people from Kaski and Nawalparasi districts felt a decreasing trend of temperature. Average 39.2 percent and in particular 56.7 percent of respondents from Kaski and 21.7 percent from Nawalparasi perceived that rainfall is increasing but it was erratic than before. Similarly, an average 32.5 percent of people had felt a decreasing trend of rainfall. The study revealed that the highest percent of respondents (65 %) from Kaski district felt an increasing trend of the hailstone. However, in the Nawalparasi district, 61.7 percent of people felt the hailstone trend is decreasing than before. This study revealed that 48.3 percentages of respondents from Kaski perceived thunderstorms, which was increasing than before but 35 percent of respondents from the Nawalparasi district felt as decreasing trend of thunderstorms. 13 percent of respondents from Kaski and 11.7 percent from Nawalparasi district had felt no change in thunderstorms as compared to previous years (Figure 2). Our result is similar to Maharjan *et al.* (2011) reported that farmers perceived more climatic stresses such as drought, flood, erosion, hail and wind storm during recent years as compared to past in the western region of Nepal. In farmers group discussion, farmers reported more incidence of crop disease and pests, need of more irrigation than before, change in seasonal cropping calendar, delay in onset of monsoon, low crop production and productivity than before and loss of indigenous varieties of rice crop were noted as the negative effects of climate change.

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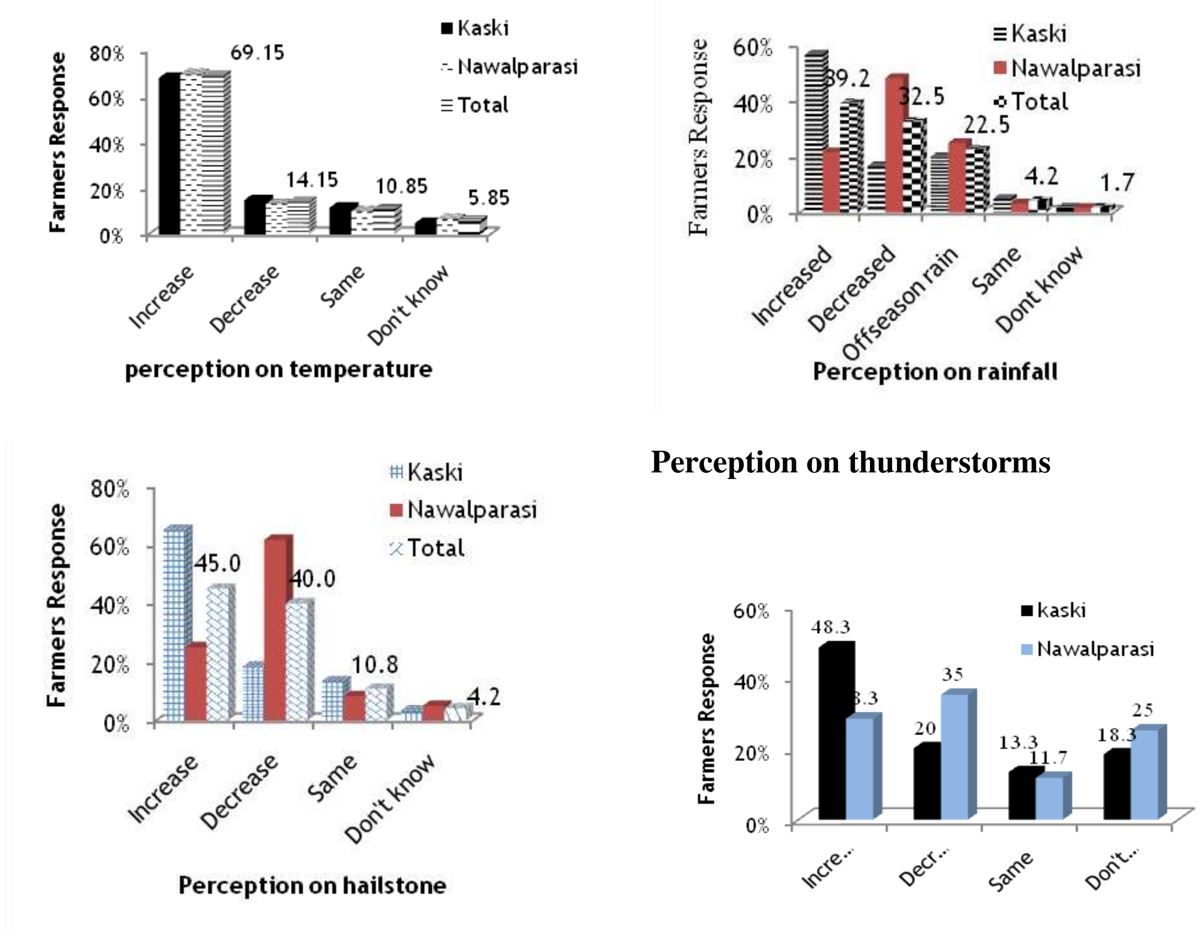

Figure 2: Perception of farmers on changing climatic parameter

Scaling of Major Climatic Hazards or Extremities

Climate hazard in the study area is grouped into five main categories (Figure 1). Respondents in Kaski district rank hailstone as a major problem and extreme hot as minor one while in Nawalparasi district respondents felt that drought was a major problem and rank that extreme cold as minor. Detailed perception of farmers regarding climatic hazards is depicted in Table 3.

Table 3: Perception of farmers regarding major climatic hazards

Climatic hazards	Kaski		Nawalparasi	
	Scale value	Rank	Scale value	Rank
Drought	0.68	II	0.96	I
Flood	0.36	III	0.56	III
Hailstone	0.76	I	0.48	IV
Extreme hot	0.28	V	0.92	II
Extreme cold	0.32	IV	0.28	V

CONCLUSION

Farmers realized the change in climate over the years. The study showed average of 69.15 percent respondents perceived the increase in temperature, 39.2 percent respondents felt

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increased in rainfall, and average of 45 percent respondents perceived the hailstone was increasing than before. The perception of farmers was partly matched with trend analysis of climatic data. The panel data regression model revealed that seasonal total rainfall showed a statistically significant linear relation on rice production. The role of seasonal rainfall was critical for increasing rice production in the study sites. The major climate change associated problems faced by the farmers of the study area due to climate change were prioritized as drought, flood, hailstone, extreme hot and extreme cold. Considering the findings of this study, we suggest adoption of appropriate climate change adaptation and mitigation practices and strategies such as (i) Use of seasonal irrigation for rice including rainwater harvesting technology and other resource conservation technologies and practices such as drought-tolerant rice varieties (e.g. Sukha dhan series) and direct-seeded rice cultivation in drought condition and use of water drainage, flood control and submergence tolerant rice varieties (e.g. Sub1 varieties); (ii) Research on impact of climate change on production of different crops and their adaptation and mitigation strategies; (iii) Promotion of both indigenous and improved climate-resilient crop varieties and adaptation practices including the use of local skills and resource that are economically feasible, ecologically sound and socially acceptable, (iv) policy support and market incentives for availability of seasonal water including adaptation and mitigation to changing climate. Further in-depth study in this regard, as well as studies on adaptation and mitigation strategies to adapt to changing climate, is imperative.

Authors' Contributions

PP and DD designed the desk research protocol. PP collected data, analyzed data and wrote the first draft where DD, DG, HKP, RPM provided critical feedback. All authors reviewed critically and accepted final manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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