Climatic and Socio-Economic Factors Influencing the Adoption of Spring Crops under Rice-Wheat System: A Case Study in the Tarai Region of Nepal

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Abstract

Sustainable intensification is considered a key strategy to harmonize economic and environmental goals in rice-wheat cropping system in the developing countries. This strategy encourages farmers to grow spring season crops in the land remaining fallows after harvesting wheat. This paper explores the impact of climatic, demographic, economic and institutional variables on area under spring season crops. Data for the study were collected from 640 households spreading across the eight Tarai districts of Nepal in 2010. The major crops grown in the spring season are mungbean, maize and rice, and farmers allocate difference amount of their land for these crops. So, three crops specific regressions were modeled through Tobit regression with the assumption that households' allocate their lands considering the potential benefit they get from these crops during the spring reason. Result shows that rainfall has positive impact on maize and rice; whereas, it is negative on mungbean. Similarly, this study reveals that male-headed households allocate larger amount of their lands for each of these crops than female-headed households. This is due to better access of fertilizers and training to male-headed households. Moreover, higher operational holders allocate more land for the spring season crops as compared to their counterparts.

Key words: Spring season, gender, cropping system, tobit model

1. Introduction

Sustainable intensification is a crop production strategy where output from lands is envisioned to increase without adverse environmental impacts, and without bringing additional lands under cultivation. This strategy is important to address the key challenges of the agriculture sector in the developing countries such as yield stagnation, land degradation, climate stress, and so on. The public attention on crop intensification has been increased when the United Kingdom Royal Society's highly influential report 'Reaping the benefits that explore the future of crop production' published in 2010

(Garnett et al., 2012). Sustainable intensification is considered quite relevant in rice-wheat (R-W) system. The R-W system is the practice of growing wheat after rice in sequence in the same piece of land, which is popular in Indogangetic plains (India, Nepal, Bangladesh, Pakistan) (Timsina and Cornor, 2001). This system contributes 45% of the digestible energy, and 30% of total protein supplied in human diet in the world (Evans, 1993). Though the traditional concept of R-W system is growing only rice and wheat, this system is being further intensified through the integration of spring season crops that are grown after wheat harvest before planting next year's main season rice. This enhances productivity of R-W system, and increases environmental conservation by minimizing volatilization of nitrous oxide (Chen et al., 1997; Pandey et al., 2008); enhancing soil fertility, microbial diversity and soil aeration (Devkota et al., 2006) (Ladha et al., 2003; Khanal and Maharjan, 2012). Smallholder farmers, whose livelihood is mainly depend on agriculture, are expected to benefit more from this strategy (Ladha et al., 2003; Khanal et al., 2006; Gauchan and Khanal, 2007). However, there are limited empirical studies explaining farmers' behaviors in growing spring season crops in R-W system, and also the available studies are based on researchers' managed experiments. It means these studies have ignored the roles of farmers' resource endowment and climate factors on households' decision for land allocation for spring season crops (Subbarao et al., 2001; Gauchan and Khanal, 2007; FORWARD, 2010). To address this knowledge gap, this study intends to analyze the farmers' behavior in allocating lands for producing different spring season crops.

2. Methodology

2.1 Study site and sampling technique

A field survey was carried out during 2010 in Nepal. A total of eight Tarai districts (70m amsl to 550m amsl): Morang, Saptari, Siraha, Dang, Kapilvastu, Banke, Kailali and Kanchanpur were purposively selected for the study, and these districts represent geophysical, climatic and socio-economic variations exist across the Tarai region (Figure 1). The Tarai region is the major food basket of the country, which contributes over 60% of the total major food crop produced in the country, and it holds enormous potential for intensification of land by introducing spring season crops in the rice-wheat system (MoAC, 2013). In each of the selected districts, five village development committees (VDCs), the lowest administrative unit of Nepal, were randomly selected. Then, two wards from each of the selected VDCs, and eight households (HHs) from each of the selected wards were randomly chosen for household survey, making the total sample size of 640 (8 HHs x 2 wards x 5 VDCs x 8 districts). A semi-structured questionnaire was used for household survey, and it was validated in five household not selected in the study sample to enhance the precision of data collection. Group discussions were also organized at ward levels to collect additional information not covered from household survey. Similarly, this study utilizes climatic data (rainfall, maximum temperature and minimum temperature) collected from Department of Hydrology and Meteorology of Nepal covering the period of 35 years (1975 to 2010). For this, climate data were collected from nearby stations of concerning districts, and climate normal values (Cabas et al., 2010) of the climate variables were calculated. In case of rainfall, the normal value was calculated as the total amount of rainfall received by households during four months period that represents the spring season (February to May). However, in case of maximum and minimum temperature average daily temperature for the aforementioned four months was estimated and used in the analysis.

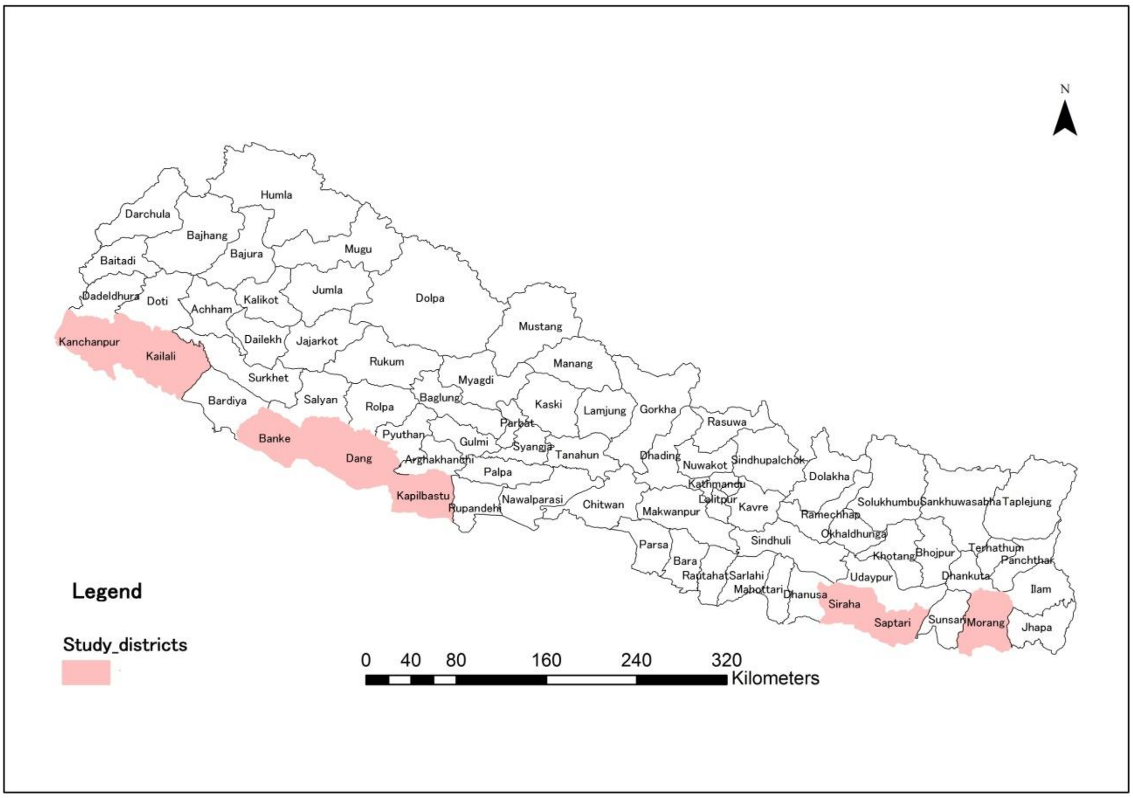

Figure 1. A map of Nepal showing study districts

Source: Raw data collected from Hydrology and Meteorological Division Kathmandu Nepal

2.2 Empirical technique

2.2.1 General background of model

The Tobit model developed by Tobin (1958) was employed for data analysis. This model has advantage of providing an explicit link between the data-generating mechanism of both zero and non-zero data by offering a variety of specifications of latent variables and censoring mechanisms and restricting the distribution of the non-censored data to have positive support. Because of its flexibility in modeling this kind of mixed data, the Tobit model has recently attracted much attention in the statistical literature. The tobit model has been frequently used in the literature to address the censoring issue. For example, Yen et al. (2003) analyzed participation and consumption decision using this model. Similarly Yen and Lin (2006) and Harris and Shonkwiler (1997) used this model to analyze the demand systems in agriculture.

Theoretically, the tobit regression is expressed in equation 1.

$y_I^* = y_I$ if $x_i\beta + \varepsilon_i$……………………(1)
$y_i = y_i^*$ if $y_i>0$, and $y_i = 0$ if $y_i = 0$

Here, y_I^* is latent variable, y_i is observed output (area under production), x_i indicate explanatory variables of the model, β is vector of coefficients, and ε_i represent error term. Multivariate tobit model could be applied to analyze this type of data but we drop this method because error terms of the crop specific equations were not correlated with each other.

2.2.2 Selection of variables and operational model

A set of 11 explanatory variables was chosen for the study. These variables were selected based on production theory i.e., farmers allocate their land considering maximizing their benefits from the production process. Further, these variables are classified into climatic and socio-economic. The impact of rainfall on area of these crops was assumed positive as they are grown during the dry season and increased water availability could motivate farmers for the production of these crops. Warming was considered negative on areas of these crops because it could enhances the severity of diseases and pests and thus reduce crop productivity (Knox et al., 2011)

The socio-economic variables considered in this study are classified into three groups: demographic, economic and institutional. Gender and education of household head (HHH), and family labor are the demographic variables and impact of these variables on land allocation for spring crops was assumed positive. Gender represents male-headed households and this category of households could have higher risk bearing capacity as compared to their counterparts (Khanal and Gauchan, 2007). Similarly, education reflects creativity of households for innovation and maintaining better linkage with extension agencies (Piya et al., 2012; Khanal and Maharjan, 2014). So, higher educated households were assumed to allocate higher proportion of their land for spring season farming. Family labor represents the proxy variable for timely implementation of crop husbandry practices in rural areas, and it was measured in in labor force unit (LFU)[1]. So, it was assumed to have positive influence in allocating higher amount of land for spring season crops. Economic variables: operational land, irrigation facility, livestock, fertilizer and cash income were also assumed to have positive impact on land allocation for the spring crops considering their linkage with maximizing benefits from crop intensification. The variable livestock represents the amount of organic manure applied in the crop field, and it was measured in livestock standard unit (LSU)[2]. Similarly,

The institutional variable chosen in this study is the access to training. Farmers get agricultural training from government and non-government organizations. Those receiving trainings from these organizations are more likely to access information about the production of spring season crops from extension agencies. The summary of variables included in the model is given in Table 1 and Table 2. The crop specific operational models used in this study are presented in equation 5, 6 and 7, respectively.

$$\text{Mungbean} = \beta_0 + \beta_1\text{RAIN} + \beta_2\text{MAXT} + \beta_3\text{MINT} + \beta_4\text{gender} + \beta_5\text{education} + \beta_6\text{labor} + \beta_7\text{ livestock} + \beta_8\text{land} + \beta_9\text{irrigation} + \beta_{10}\text{ training} + \beta_{11}\text{ income} + \varepsilon_1 \quad (5)$$

$$\text{Maize} = \alpha_0 + \alpha_1\text{RAIN} + \alpha_2\text{MAXT} + \alpha_3\text{MINT} + \alpha_4\text{gender} + \alpha_5\text{education} + \alpha_6\text{labor} + \alpha_7\text{livestock} + \alpha_8\text{land} + \alpha_9\text{irrigation} + \alpha_{10}\text{training} + \alpha_{11}\text{income} + \varepsilon_2 \quad (6)$$

$$\text{Rice} = \gamma_0 + \gamma_1\text{RAIN} + \gamma_2\text{MAXT} + \gamma_3\text{MINT} + \gamma_4\text{gender} + \gamma_5\text{education} + \gamma_6\text{labor} + \gamma_7\text{livestock} + \gamma_8\text{land} + \gamma_9\text{irrigation} + \gamma_{10}\text{training}\ \gamma_{11}\text{ income} + \varepsilon_3 \quad (7)$$

Where, β, α and γ are the vectors of coefficients associated with the explanatory variables, and ε_1, ε_2 and ε_3 are the error terms for the crop specific equations. Before running the tobit model, data were validated for multicollinearity, heteroskedasticity and endogeneity issues.

3. Results and discussion

3.1 Summary of study households

It was found that during the spring season farmers grow mainly four crops: mungbean, maize, rice and vegetables (mainly cucurbitaceous vegetables such as bottle gourd, bitter gourd, pumpkin, and sponge gourd). The proportion of households growing mungbean, maize, rice and vegetables is 9.21%, 12.03%, 7.19% and 3.43%, respectively (Table 1). Majority of the surveyed households (60.32%) do not grow any spring season crops. Similarly, those growing spring season crops use 45.6% of their total operational land in this season. As the proportion of households growing vegetables during spring season is quite low, this variable was dropped from the analysis. So, only mungbean, maize and rice were used as dependent variables in the tobit model.

Table 2 shows mean and standard deviation of the selected explanatory variables used in the analysis. Households receive 167.04 mm rainfall during the spring season, and there is increasing trend of rainfall in the season (Figure 2). Moreover, the variability of rainfall also creates risks of crop failure because these crops are mainly grown in rain fed environments. Similarly, there is variability in maximum and minimum temperature but the magnitude of this variation is less than that of rainfall.

3.2 Result of tobit model

This study shows that the selected variables fit in the model well. This is clear from significant likelihood ratio test ($p<0.05$), and it indicates that coefficients of the selected explanatory variables are significantly different from zero (Table 3).

The direction of impact of most of the selected variables is as per the expectation with some exception. Since the model was estimated using maximum likelihood method, the coefficients of explanatory variables do not represent their average impact on dependent variables. To address this issue, marginal effect[3] of the selected independent variables were estimated and used for discussion in this study.

Rainfall has significant negative impact on mungbean cropped area whereas it is just opposite for maize and rice. This indicates that households prioritize maize and rice in higher rainfall area. The maximum temperature shows significant negative impact on all of these crops. Associated reason for this is not clearly understood but households realizing higher maximum temperature realized higher disease pressure in case of mungbean. In contrary to this, the influence of minimum temperature is positively significant in mungbean and rice but it is negative for maize.

Among the socio-economic variables, the gender of HHH has significant positive impact on operational land of the selected crops. This implies that male-headed households allocate higher proportion of their land for growing these crops than female-headed households. In case of mungbean male-headed households put 5.25 kattha additional land as compared to female headed ones, and impact of the gender is even more on maize and rice.

Operational land shows positive impact on all the crops considered in the analysis though significant impact has been observed only in mungbean. This might be due to the higher risk bearing capacity of larger operated land in mungbean cultivation. Though there is no significant impact of livestock (LSU) on cropped area of the selected spring crops, the direction of impact is as per hypothesized in rice but it is opposite in maize and mungbean. The negative influence of LSU on mungbean area might be due to the prioritization of better fertile soil for maize and rice. Being a leguminous crop mungbean does not require as much as soil fertility as other two crops do. Similarly, there is positive impact of households' annual cash income on land allocation for the spring season crops but it is only significant in rice. It might be due to ability of higher cash generating households to implement crop husbandry practices on time. Because rice is more inputs intensive crop as compared to mungbean and maize, the impact of cash income became visible (significant) in rice. Training was assumed to have significant positive impact on land allocation across these crops but it is not significant. As per the expectation, the influence of irrigation is positive, which means those with irrigation allocates higher amount of land for spring crops

4. Discussion

This study shows that majority of land remains fallow after wheat harvest across the study area. Subbarao et al (2001) have also identified huge fallow land (3.9 million ha) area in Nepal's Tarai after rice though it does not separate which season's (winter or spring) fallow is more severe. During group discussion sessions, farmers argued that land remains fallow for about 60 to 120 days in the spring season (Table 4). In low land areas (high soil moisture regime where farmers grow long duration rice varieties, for example Basmati) farmers could not grow wheat due to excessive moisture during wheat planting. However, this category of land becomes suitable to grow spring season crop after drying up excess moisture. Farmers argue that they could grow crops in such land about 20-25 days earlier than the normal spring season planting season (where wheat is grown).

Among the climatic variables, there is significant impact of rainfall and maximum temperature though the direction of impacts varies across the crops. The significantly positive impact of rainfall on rice and maize but negative on mungbean elucidates the farmers' behavior in prioritizing more profitable and stable crops in the better production environments. Mostly farmers were found to have grown local landraces of mungbean that are long duration and susceptible to Yellow Mosaic Virus. This does not mean that growing mungbean is less profitable than either of these crops. Khanal et al (2006) found higher gross profit from mungbean production as compared to rice production while comparing improved rice variety (Hardinath 1) and improved mungbean variety (Prateeskha). The less profitability of rice was due to higher costs in irrigation, fertilizer and land preparation. In contrast to above study, majority of the mungbean growers (62%) have argued less profitability from mungbean is less as compared to rice, and associated reason might be due to the fact that most of the mungbean growers (72%) produce local mungbean varieties that are low yielding and susceptible to Yellow Mosaic Virus. These varieties are grown mainly for green manure. The negative impact of maximum temperature on production area of these crops might be due to moisture stress.

This study clearly shows the significant role of gender of household head in the production area of all three spring crops included in this study. As shown in Figure 3, households grow mungbean on an average 0.532 kattha of land but male headed households grow this crop in larger area (0.623kattha per household) than that of female-headed ones (0.202 kattha per household). Similarly, male-headed households allocate larger amount of their land in maize than their counter part. The average land allocation for rice was 0.712 kattha per household, and male-headed households also grow rice in larger area as compared to the female-headed ones. Gender role in this case can be discussed from two perspectives. First, male-headed households are better off in making contacts with research and development organizations. Second reason for the better performance of male-headed households in growing spring season crops in higher proportion of their land is related to risk management concern. Growing the spring season crop is recent phenomenon in the study area as farmers used to keep their land fallow for free grazing after wheat harvest. There is normally shortage of fodder stock at household level at this time, and those wanting to grow crop during spring season should face risk of crop failure due to free grazing. The better performance of male-headed households in bringing larger proportion of their land for spring crops cultivation is due to their better capacity in adopting risk management measures. The risk management measure in this case is the adoption of penalty measure against those letting their animal for free grazing during the spring season. In a group discussion, farmers argued that in Kapilvastu they had adopted penalty schemes for those not obeying the rules set by the farmers' groups in partnership with local government agency (police station). The penalty scheme is based on the proportion of crop damaged by animal, and decided by the groups. Again, those taking leadership in this initiative were male-headed households. Though family labor was assumed to have positive impact in the land allocation, this study shows that it has rather negative impact on them. It might be due to the fact that even having sufficient labor at households; farmers could not increase their spring crop area due to lack/limited irrigation facility.

The significantly positive impact of land on maize and mungbean area and negative on rice area implies the small farmers' behavior in prioritizing rice crop. As rice is the main food crop of the Tarai region, farmers go for other crops such as maize and mungbean once their operational lands increase. This might be due to the fact that growing mungbean and maize in the spring season is a new practice in the selected districts.

5. Conclusion

In this paper, we analyzed households' behavior in allocating lands for spring season crops in the rice-wheat system. Understanding farmers' behavior in adopting additional crops in this system is important to enhance food security of people in the developing countries. It was found that major portion of farmers' land remains fallow during the spring season, and the popular crops grown in the season include rice, maize and mungbean. This paper discussed farmers' behavior in allocating lands for cultivating these crops using tobit model, and the result shows that households receiving higher amount of rainfall are prioritizing maize and rice, and this is just opposite in case of mungbean. However, maximum temperature discourages farmers in allocating higher proportion of their land for spring season crops, which might be due to increased moisture stress as a result of higher temperature. Another interesting finding from this study is that there is significant positive impact of male-headed households in prioritizing land for spring season crops. This implies the necessity to empower women farmers for their role in designing and implementing measures for controlling free grazing scheme in the study area. This study also recognized the positive role of larger farmers in the allocation of their lands for spring season crops. It implies the necessity to address small farmers' constraints in accessing agricultural inputs, and controlling free grazing.

End notes

[1]LFU is the measurement of labor force, where people from 15-59 years old regardless of their gender were categorized as 1 person = 1LFU, but in case of children (10-14 years old) and elderly people (>59 years old) 1 person = 0.5 LFU

[2]LSU is the aggregates of different types of livestock kept at household in standard unit calculated using the following equivalents; 1 adult buffalo = 1 LSU, I immature buffalo = 0.5 LSU, 1 cow = 0.8 LSU, 1 calf = 0.4 LSU, 1 pig = 0.3 LSU, 1sheep or goat = 0.2 LSU and 1 poultry or pigeon =0.1 LSU (CBS, 2003).

[3]Marginal effect on the latent dependent variable $y^* = \frac{\partial E(y^*)}{\partial x_k} = \beta_k$

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Table 1. Summary of dependent variables used in the study

Crops	N	Land (kattha)	Standard deviation	Minimum	Maximum
Mungbean (Mu)	59 (9.21)	5.8	7.11	0.25	50
Maize (Ma)	77 (12.03)	7.5	7.54	0.25	40
Rice (R)	46 (7.19)	9.59	6.4	3	30
Vegetables (V)	22 (3.43)	1.51	0.87	1	4
Mu+Ma	2 (0.31)	4.36	1.06	1.5	3
Mu+R	3 (0.47)	2.7	2.38	1	4
Mu+V	6 (0.94)	3.41	2.48	1.5	5
Ma+R	23 (3.59)	4.58	3.47	1	6
Ma+V	8 (1.25)	3.65	3.51	2.45	6.2
Mu+Ma+R	3 (0.47)	2.58	3.14	1	4.5
Mu+Ma+V	1 (0.16)	1			

Ma+R+V	3 (0.47)	1.8	1.59	0.5	2.75
Mu+Ma+R+V	1 (0.16)	2			
Fallow	386 (60.32)				

Figures in the parentheses indicate percentage; N = 640; 1 kattha = 0.3ha

Source: Survey, 2010

Table 2. Summary of explanatory variables

Variables	Definition	Mean	Standard deviation	Expected sign
RAIN	Total rainfall (mm)	167.04	46.80	+ve
Tmax	Maximum temperature (^{O}C)	31.64	0.89	-ve
MINT	Minimum temperature (^{O}C)	16.48	0.82	-ve
Gender	Sex of household head, 1 for male and 0 for otherwise	0.73	0.26	+ve
Education	Formal education of household head (years)	8.49	4.04	+ve
Labor	Labor force unit (LFU) at household	3.45	1.25	+ve
Livestock	Livestock Standard Unit (LSU)	3.16	2.25	-ve for mungbean but +ve for maize and rice

Land	Households' total operational land (kattha)	22.96	26.64	+ve
Land tenancy	If land under share cropping =1, and 0 for otherwise	0.31	0.12	+ve
Irrigation	1 if household has access to irrigation facility, and 0 for otherwise	0.228	0.420	+ve
Training	1 if household attended agricultural training and 0 for otherwise	0.082	0.275	+ve
Fertilizer	Application of chemical fertilizer (NRs/year/kattha)	4.68	3.47	-ve
Income	Households' annual cash income (NRs)	119,743	128,566	+ve

Table 3. Impact of climatic and socio-economic variables on area of different crops

Variables	Mungbean	Maize	Rice
RAIN	-0.004 (-0.002)***	0.005 (0.004)**	0.0046 (0.006)***
MAXT	-0.332(-0.181)***	-0.522 (-0.478)***	-0.533 (-0.524)
MINT	0.367 (0.149)***	-0.097 (-0.0087)	0.039 (0.025)
Gender	0.147 (0.120)*	0.372 (0.287)**	0.581 (0.467)**
Education	0.014 (0.007)	0.121 (0.104)	0.032(0.271)
Labor	- 0.002 (-0.001)	-0.084 (-0.074)*	-0.162 (-0.087)***
Livestock	-0.034 (-0.013)	0.057 (0.247)	0.160 (0.147)***
Land	0.004 (0.0032)***	0.012 (0.004)**	-0.007 (-0.004)
Tenancy	0.193 (0.147)	0.443 (0.418)	0.087 (0.057)
Irrigation	-0.267 (-0.254)**	-0.425 (-0.413)	-0.676 (-0.541)
Training	0.177 (0.76)	-0.093 (-0.078))	0.052 (0.047)
Chemical fertilizer	-0.0025 (-0.0014)	-0.0038 (-0.0032)	0.003 (0.002)*
Income	0.0001 (0.0001)	0.0001 (0.0001)	0.0012 (0.0004)**

Constant	5.38 *	16.23*	14.5**
Model summary	N = 640, Log likelihood = -1098.7, LR = 74.36***; Pseudo R^2 = 0.24	N = 640, Log likelihood = -1683.42, LR = 90.51***; Pseudo R^2 = 0.26	N = 640, Log likelihood = -1560.4.42, LR = 148.43***; Pseudo R^2 = 0.19

Note: Values in the parenthesis indicate marginal effect; *,** and *** indicate significant at 10%, 5% and 1% level of significance

Table 4. Availability of fallow lands in the study area

Cropping patterns	Fallow days	Spring crop planting time
Rice-fallow	100-120	February
Rice-wheat-fallow	60-80	March/April
Rice-potato-fallow	80-90	March/April

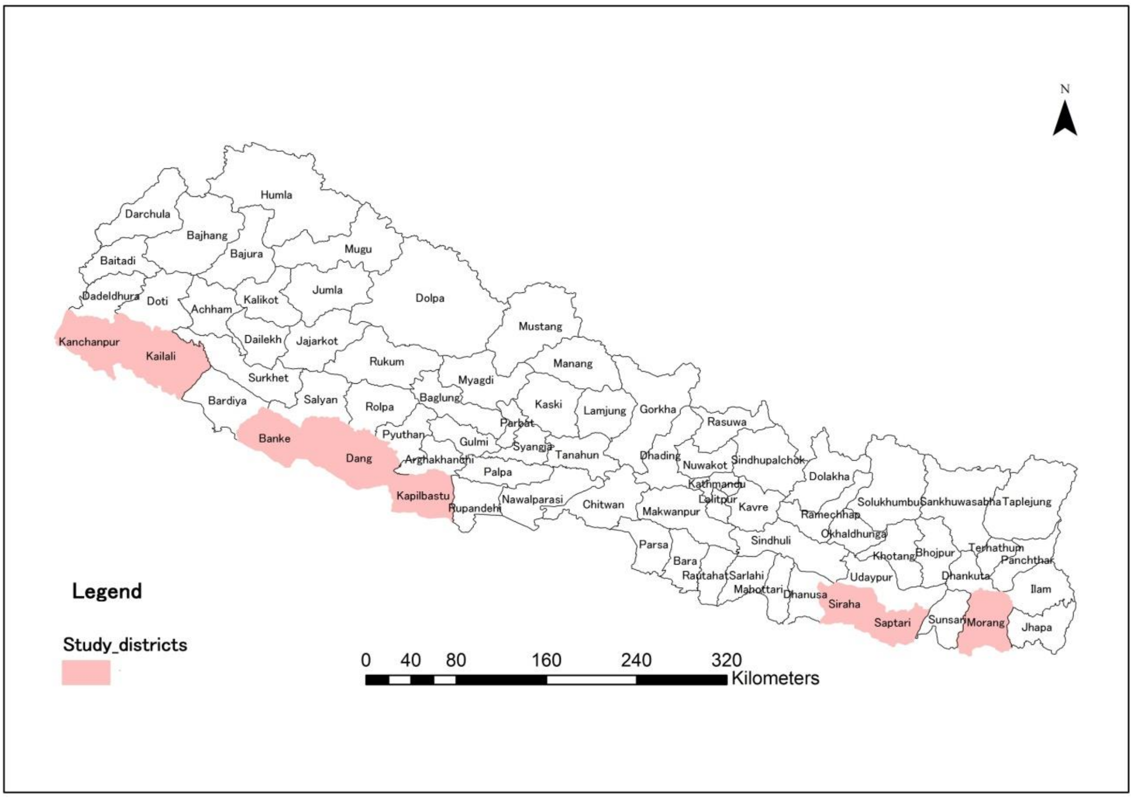

Figure 1. A map of Nepal showing study districts

Source: Raw data collected from Hydrology and Meteorological Division Kathmandu Nepal

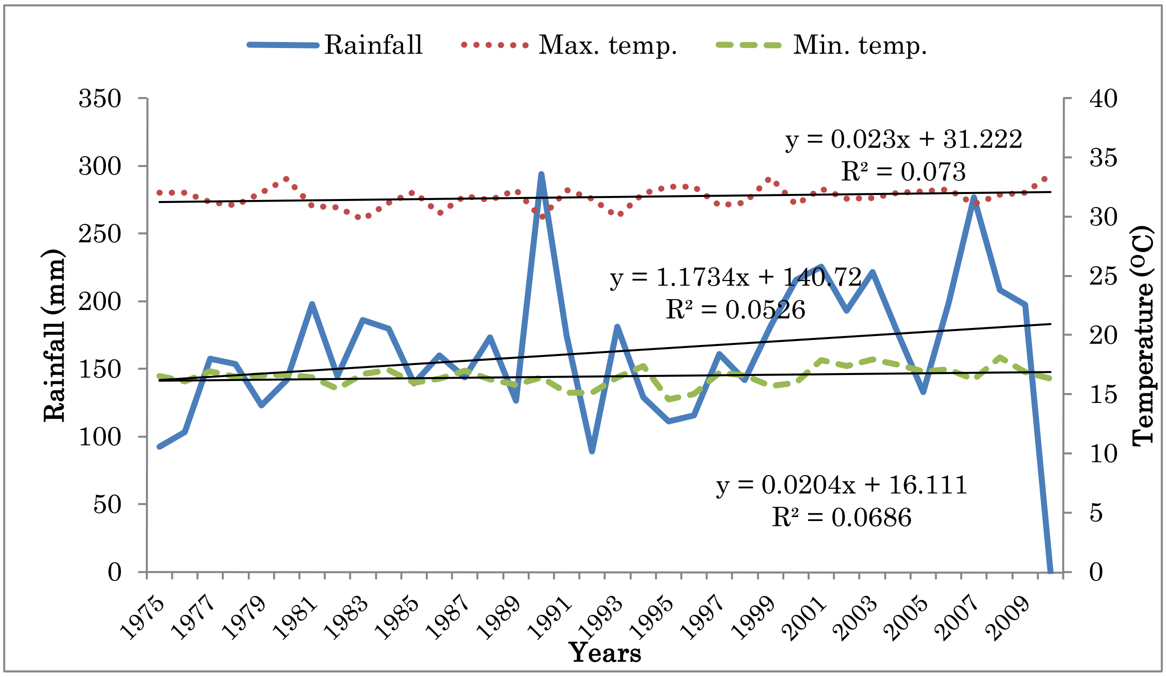

Figure 2. Climate trend in the study area

Source: Raw data from Department of Hydrology and Meteorology, Nepal

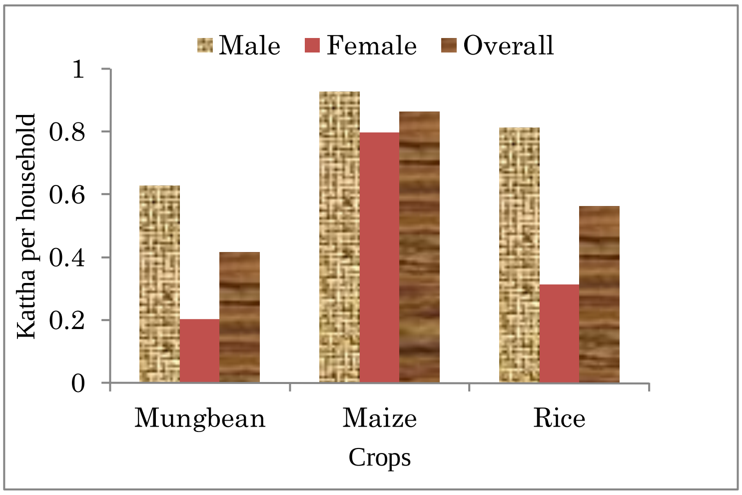

Figure 3. Gender-wise distribution of spring crops

Source: Field Survey, 2010

Annex 1. Description of meteorological stations considered in the study

District	Stations	Logitude	Latitude	Altitude
Kanchanpur	Mahendranagar	80.01	29.03	176
Kailali	Tikapur	81.07	38.53	140
Banke	Khajura	81.37	28.1	190
Dang	Tulsipur	82.18	28.13	725
Siraha	Lahan	87.17	26.73	138
Saptari	Rajbiraj	86.45	26.55	91
Morang	Biratnagar	87.16	26.48	72