Relationship between Climate Variables and Yield of Food Crops in Nepal: Cases of Makwanpur and Ilam District

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Abstract

Agriculture, being sector largely dependent on climate variables, will be adversely affected by climate change. Therefore, this paper intends to assess how the recent trends of climate variables are affecting yields of major food crops in two hilly districts of Nepal namely, Makwanpur and Ilam based on district level data from 1978-2008. Trends of climate variables show that maximum and minimum temperature in summer as well as winter temperatures are increasing in Makwanpur, but in Ilam minimum temperature in both season shows declining trend. In case of rainfall, it is in increasing trend only during summer in Makwanpur. In all cases inter-annual variation of rainfall is very high. In contrast, crop yield shows some steady trends but in both directions; increase as well as decrease. For instance, except the yield of paddy and maize in Makwanpur, and maize and millet in Ilam all other food crops are in increasing trend. Among these food crops potato shows the highest rate of yield increase. Relating the trends of climate variables with yield of food crops shows that the current trend of minimum temperature has adversely affected yield of maize and paddy in Makwanpur, whereas in Ilam decreasing trend of rainfall has affected yield of paddy adversely. Despite the suppression of yield of these food crops by current trend of climate variables, most of these food crops overcame such suppression leading to the increase in overall yield. However, paddy, maize and millet are not able to overcome such suppression leading to decline in overall yield, thus requires special attention in order to cope with adverse effect of climate change in days to come.

1. Introduction

Climate change is the change in climatic condition over the time, which is due to natural variability or as a result of human activity (IPCC, 2001). It has been established that the climate change over the past century is due to anthropogenic activity and it will have an effect on various natural as well as man-made processes and structures. A climate change will effect natural resources, such as water, forests, etc. which will ultimately have effect on human being. The impact of climate change will be felt differently at different sectors like agriculture, water resources etc., where some sectors will be more adversely affected while some will be less adversely affected, and some will have benefit from it. As climate is one of the main factors of agricultural production, there is significant concern in the world about the effects of climate change and its variability on agricultural production (Mendelsohn, 2009). Many believe that agriculture sector is more susceptible to climate change as it depends on climatic factors like temperature and precipitation (Deschenes & Greenstone, 2006).

Agriculture is very sensitive to climatic variability such as change in temperature, precipitation and also climatic extremes like drought, flood etc. (USEPA, 2011). The effect of climate change on agriculture will be direct as well as indirect (Gbetibouo & Ringler, 2009). The direct effect of climate change on agriculture will be through changes in temperature and precipitation (WICCI, 2009). The change in temperature and precipitation will affect the phenology and timing of crop development as well as through changes in atmospheric CO_2 concentration (IPCC, 2007). Also, changes in the global climate will affect temporal patterns of temperature and rainfall at the regional level (IPCC, 1996) which will have effect on agriculture. Further, due to climate variability there will be shortening of growing periods which will reduce potential yield (Peiris, et al., 1996). Climate change will have impact on extension of agriculture growing season in the subtropical regions by changing seasonal temperature and precipitation (Reilly & Schimmelpfennig, 1999). Indirect effects will be detrimental changes in diseases, pests and weeds, decrease in water availability which will have negative impact on crop yield. Thus yield and quality of food-crops will reduce in general which will exacerbate vulnerability in food supply (Joshi, Maharjan, & Piya, 2011). In addition to this, research by Nelson et al. (2009) using the Decision Support System for Agrotechnology Transfer (DSSAT) model stated that by 2050 climate change will have negative affect on well-being of humans and agriculture. It also states that crop yield in global agriculture context will decrease and production will be negatively affected (Nelson, et al., 2009).

Nepal is a mountainous country where majority of people live in rural areas. In 2009 only 17.72% of people were living in urban areas. The agricultural land in Nepal is 42100 sq. km. as of 2009 (The World Bank, 2011). In rural area agriculture is the main livelihood option. So economy of Nepal is significantly dependent on agriculture. Approximately 33.85% of GDP came from agriculture in 2009, down from 40% in 2000. Irrigation covers only 27.74% of the total agricultural land in Nepal (The World Bank, 2011). Therefore people mostly rely on rain-fed agricultural system. Further, irrigation is mainly the small type managed by the farmers' community itself (Bhandari & Pokharel, 1999). As farmers rely mainly on rain-fed system, climate change will have more effects on them.

Analyses of data from 1976 to 2005 indicate that Nepal temperature has increased by 1.6°C which is the fastest long-term increase (Maharjan, Joshi, & Piya, 2009). In addition, warming trend in Nepal is more pronounced in autumn and winter. Nepal experiences monsoonal rains during June to September which is around 80% and very low precipitation during December to February (Ministry of Population and Environment, 2004). An analysis of temperature trend from 1976 to 2005 found that maximum temperature was increasing faster in the higher altitude than in lower altitude while annual minimum temperature trend of the country was found to be decreasing in the northern (higher altitude) part while most of the southern lower altitude part was found to be in increasing trend (Practical Action Nepal Office, 2009). This shows that there is increasing temperature anomaly in the country. Further, in 2009, there was positive temperature anomaly of over 1°C recorded in the north-western part and some areas of Eastern, Central and Western part of Nepal (Department of Hydrology and Meteorology, 2009). Nepal climate projection using general circulation model (GCM) showed that there was significant increase in temperature projection for 2030, 2050 and 2100 (Agrawala, et al., 2003). A study carried out by Chaulagain (2006) in four stations showed that there was decrease in number of rainy days in three stations while there was positive trend on number of rainy days from July to August in all stations, indicating longer duration of drought period.

The effect of climate change in agriculture will mostly be adverse as it is highly dependent on weather condition due to extreme rainfall (Maharjan, Joshi, & Piya, 2009). According to Regmi (2007), in 2005, there was 2% and 3.3% decrease in paddy and wheat production as country experienced drought. Also, paddy decreased by 27-39% in Eastern Terai in 2006 due to drought (Regmi, 2007). Sharma and Shakya (2006) state that there are changes in water availability in monsoon, pre-monsoon and post-monsoon season and shifting of the hydrograph have a direct impact on Nepalese agriculture. According to Maharjan, Joshi and Piya (2009) the rise in temperature will affect agriculture as there will be increase in incidence of pests and diseases and decreasing physiological performance. A study done by Joshi, Maharjan and Piya (2011) to see effect of climatic variables on yield of major food crops of Nepal using multivariate regression model showed increase in wheat and barley yield which is contributed by the current climatic trends whereas increased summer rainfall and temperature suppressed the yield growth of maize and millet. The study concludes that the food crops are negatively affected by climate change except for paddy which thrives on water logging condition (Joshi, Maharjan, & Piya, 2011). Further, in the study done using Ricardian method in Nepal concluded that the impact of climate change on agriculture varied with temperature and precipitation in different climatic zones (Thapa & Joshi, 2010).

As climate is an integral part of any systems, natural or man-made, any change in it will have an effect on the system. Nepal is experiencing rapid changes and pressures from climate change in different sectors (Maharjan, Joshi, & Piya, 2009). As

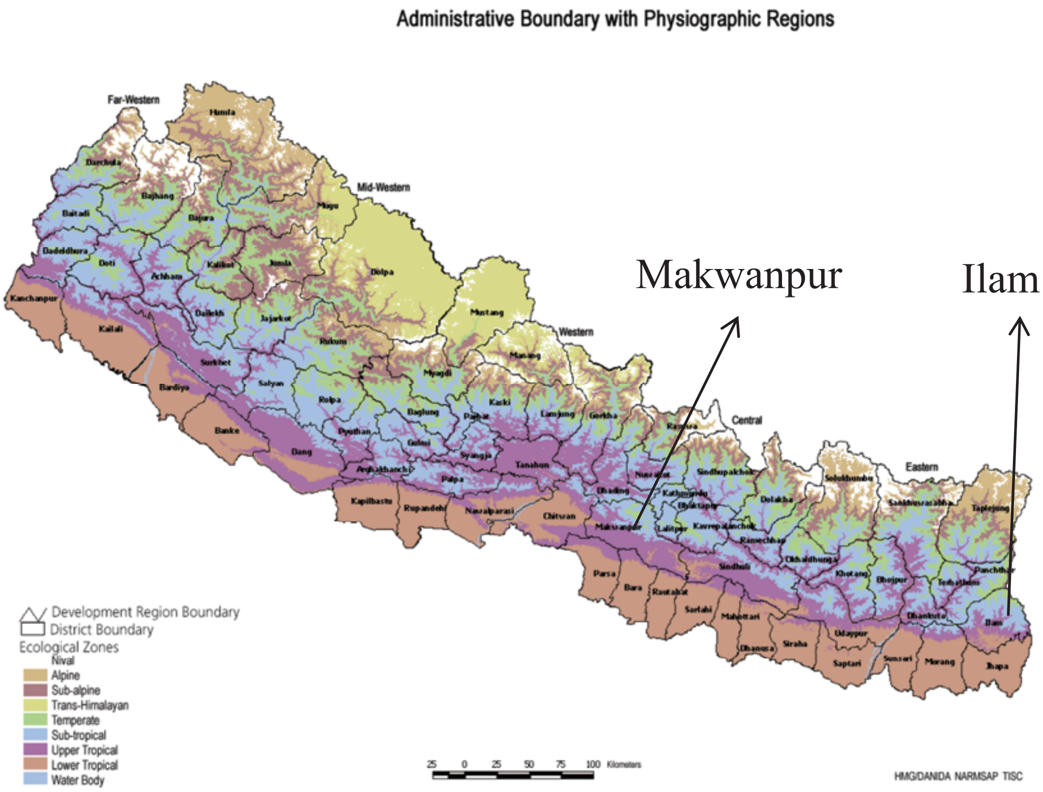


Figure 1. Map of Nepal with study districts

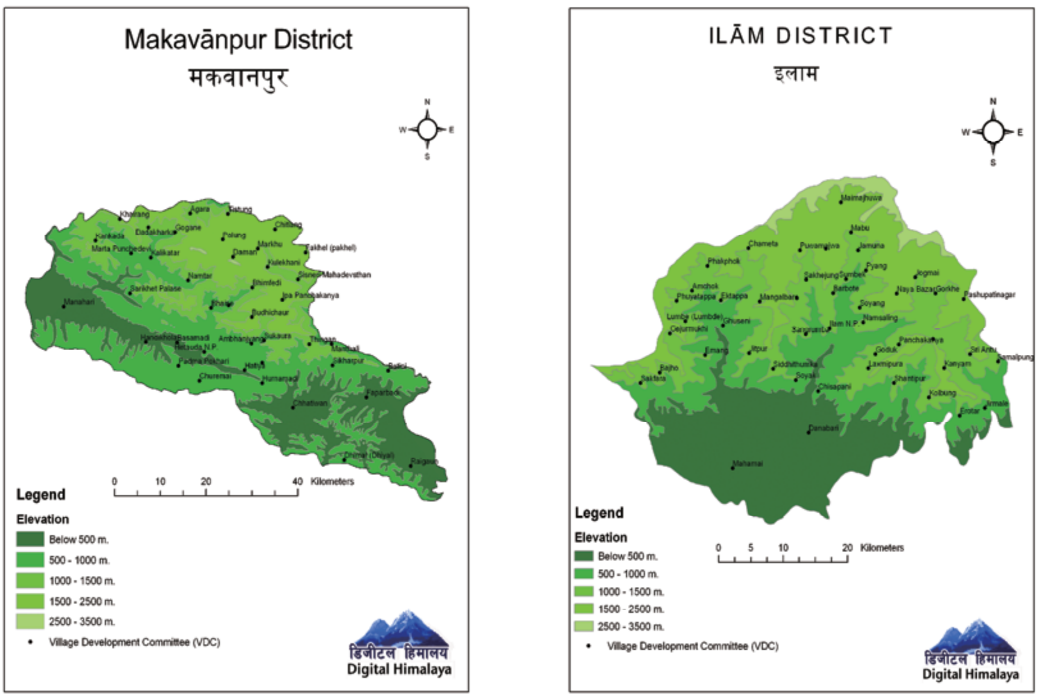


Figure 2. Map of Makwanpur (a) and Ilam (b) Districts

agriculture is one of the sectors that are more dependent on climatic factor, farmers are more prone to have impact from any changes in the climate. The change in agricultural production due to climate change will have an effect on farmers both economically as well as socially, especially to those who have little adaptive capabilities. So, it becomes very important to understand how yield of major food crops is responding to change in climate variables over time in order to understand the relation and respond to it more effectively. In addition, knowing the regional and local level impact of climate change on major food crops will help in anticipating future food security of the region and intervening accordingly. Therefore, this study tries to understand how climate variables like temperature and rainfall is changing and how such change is affecting yield of major food crops in two hilly districts of Nepal.

2. Methodology

The methodology includes the simple regression analysis in order to establish the trend of maximum temperature, minimum temperature, and precipitation of summer (May-August) and winter (November-February) seasons in Ilam and Makwanpur district from 1978 to 2008. The summer and winter seasons were taken according to the cropping season of Nepal as given by Joshi, Maharjan, & Piya (2011). Also simple regression model was run to see changes in the yield of the major food crops in Ilam and Makwanpur district namely, paddy, maize, wheat, millet, barley and potato. Further, to see the effect of climate change on the yield of the major food crops of Nepal in Ilam and Makwanpur district, multiple regression analysis (equation 1) was used as given by Nicholls (1997). This study uses the historic data of climate variables such as change in temperature and precipitation and yield data (Joshi, Maharjan, & Piya, 2011).

$$\delta W = \beta_1 \delta R + \beta_2 \delta T_{max} + \beta_3 \delta T_{min} \ldots (1)$$

Here, δW = Change in yield

δR = Change in rainfall

δT_{max} = Change in maximum temperature

δT_{min} = Change in minimum temperature

β_1, β_2 and β_3 are the coefficient of rainfall, maximum temperature and minimum temperature respectively.

In the above equation, de-trending of the yield and climatic variables was done by using residuals i.e. year to year changes in all variables (Nicholls, 1997) to calculate quantitative relationships between variations in climate and yields. This helps to nullify influences of non-climatic factors like new cultivars, changes in management practices of crops. According to Nicholls (1997) using year-to-year change will remove long-term confounding influence of management practices and these factors will appear like noise around relationship.

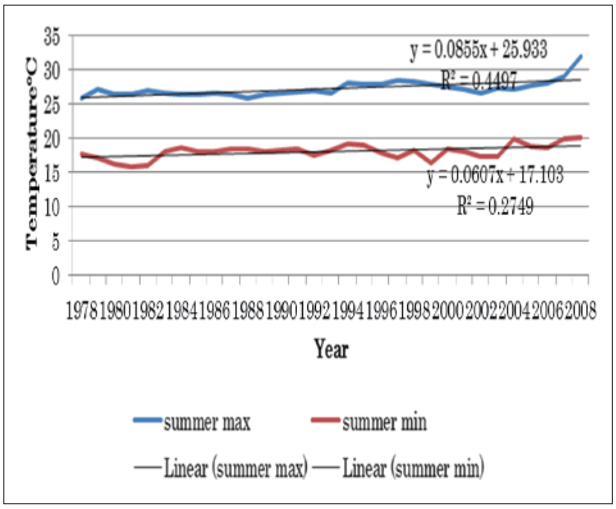
In climate change impact studies, the climatic variables that are used mostly are the temperature, rainfall and solar radiation, however solar radiation has direct relation to the maximum and minimum temperature due to radiative cooling (Peng, et al., 2004). So in this study only temperature and rainfall data are considered. Also, to capture the differential effect of day and night temperature, minimum and maximum mean air temperature is used for this study (Peng, et al., 2004). Further, in the study of crop productivity due to the effect of environmental changes mainly simulation model and regression model are used (Joshi, Maharjan, & Piya, 2011). According to Schlenker & Roberts (2008) crop simulation study will help to understand physiological effects on crops yield due to high temperature but will not incorporate the small increase in temperature associated with global warming. While based on historical climatic and yield data, predictions of yield changes due to climatic variables for specific crops are relatively accurate (Boubacar, 2010; Isik & Devadoss, 2006; Lobell & Asner, 2003; Mendelsohn et al., 1994). Further, regression analysis is replicable in other regions also (Nicholls, 1997). In developing countries like Nepal where primary livelihood of people is agriculture, there is lack of modelling studies and data on impact of climate change in agriculture, it becomes more matter of concern as there remain more uncertainties. Also, it is very much necessary to understand the impact of climate change on agriculture especially in developing countries for distributional effect of climate change as well as for adaptation and benefits from policies (Thapa & Joshi, 2010). Hence, in this study regression model is used to predict change in yield in response to climate change based on historical climatic and yield data as given by Nicholls (1997).

In this study, the major food crops of Nepal, paddy, maize, millet, wheat, barley and potato, as stated by Subedi (2003) are taken. Further, paddy, maize, potato and millet are taken as summer crops grown from May to August, and wheat and barley are taken as winter crops cultivated from November to February (Joshi, Maharjan, & Piya, 2011). Also, due to the availability of the data and its consistency, the period from 1978 to 2008 was taken into consideration for the analysis. The data for temperature and rainfall was taken from the Department of Hydrology and Meteorology (DHM), Nepal, whereas yield data was compiled from different publications of the Ministry of Agriculture and Cooperatives (MoAC).

3. Results and Discussion

3.1 Trend analysis of climatic variables

The trend analysis of climate variables was done as per the growing season of the major food crops of study districts from 1978 to 2008. For the analysis of temperature in Makwanpur, time-series data from two meteorological stations namely Daman and Hetauda were taken, whereas for rainfall, data were taken from four additional meteorological stations namely Chisapani Gadhi, Markhu Gaun, Makwanpur Gadhi and Beluwa, thus comprising total of 6 meteorological stations. In case of Ilam district, data from two stations namely Ilam Tea State and Kanyam Tea State were used to make a trend analysis of temperature, and data from three stations including Himali Gaun together with Ilam Tea State and Kanyam Tea State were used to make trend analysis of rainfall.



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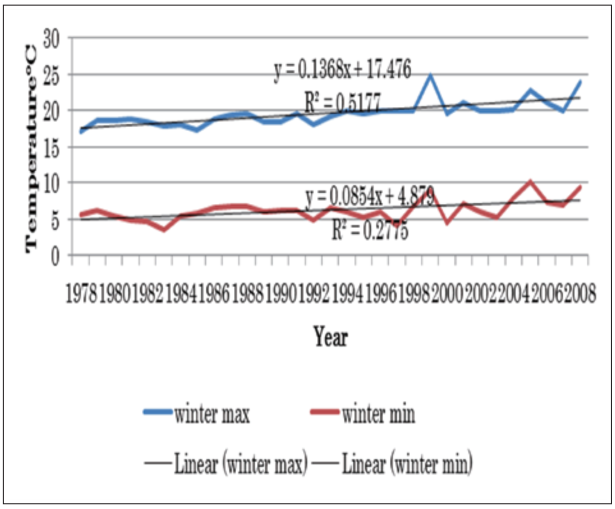

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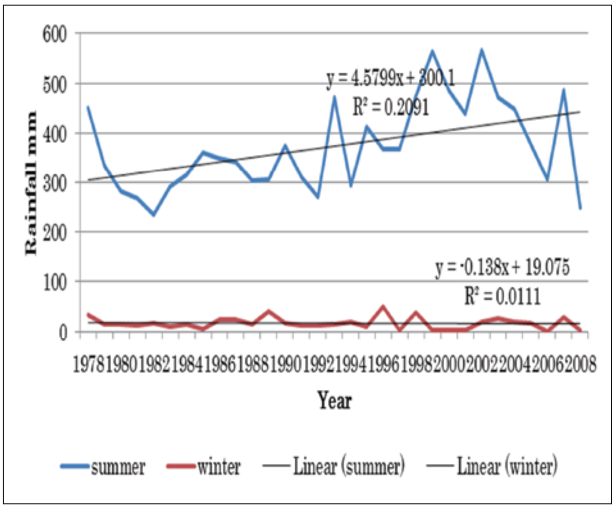

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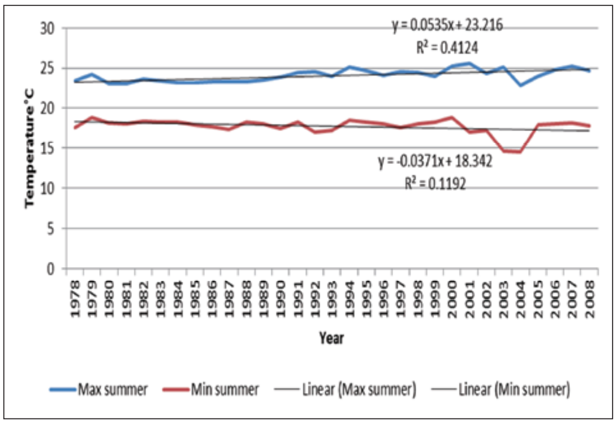
Figure 3. (a, b, and c). Temperature and rainfall trend in Makwanpur from 1978 to 2008

Seasonal trend of all climatic variables differs between the sample districts. In Makwanpur, all the coefficients except winter rain are positive, which indicates that there is increase of temperature and rainfall over the study periods (Figure 3a, 3b and 3c). Here, minimum and maximum temperatures are increasing steadily over the period at the annual rate of 0.06°C and 0.09°C respectively during summer and 0.09°C and 0.14°C respectively during winter. Trend of summer rain is significantly high indicating significant increase in rainfall over the period (Figure 3a and 3b). However, there exists high inter-annual variation in summer rain. Winter rain, on the other hand, shows steady decline overtime with less inter-annual variation (Figure 3c). High inter-annual variable during summer will have adverse impact on agriculture as still significant proportion of cultivable land is under rainfed agriculture.

In contrast to Makwanpur, many of the climate variables have negative trend coefficient in Ilam. Here, though maximum temperatures in both seasons are increasing at the annual rate of 0.05°C and 0.07°C respectively, minimum temperature is decreasing in both seasons. This suggests increase in temperature gap between the day and night temperature. Increase in such gap is also considered to have adverse impact on yield of agriculture crops (Abrol & Ingram, 1996). Rainfall for both seasons is also is in declining trend in Ilam, which will hamper rain-fed agriculture to a greater extent.



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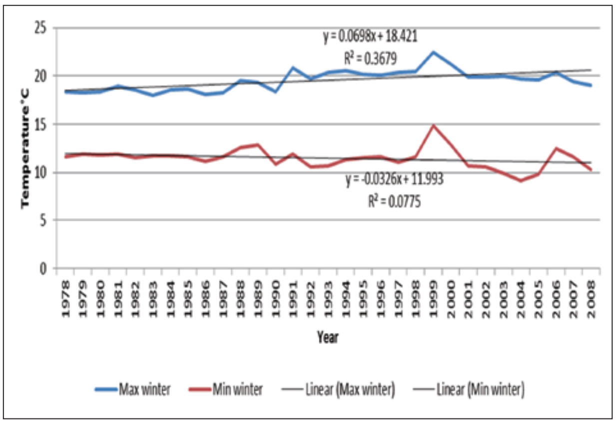

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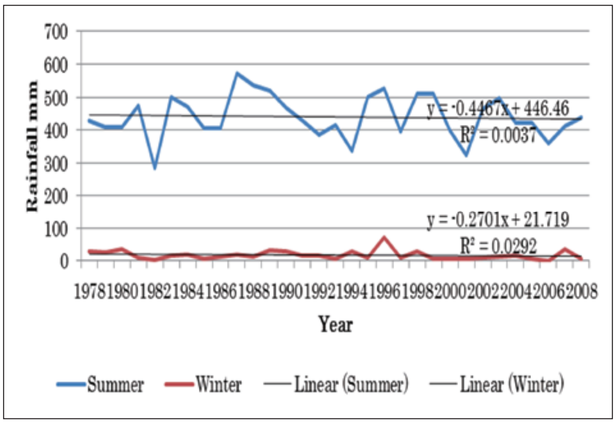

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Figure 4. (a, b, and c). Temperature and rainfall trend in Ilam from1978 to 2008

3.2 Trend analysis of yield of major food crops in Nepal

The major food crops of Nepal namely paddy, wheat, maize, millet, barley and potato yield from 1978 to 2008 was analysed using simple linear regression model. The analysis shows that in case of Makwanpur district yield of paddy and maize is slightly decreasing with coefficient of -12.56 and -10.047 respectively. While other major food crops like millet, potato, wheat and barley are increasing with coefficient of 6.4, 226.58, 34.4, and 17.48 respectively. In case of both districts, coefficients of potato yield are quite high followed by wheat. Such high coefficients indicate that high increase in yield is attributed to change in crop management practices. However, the main interest of this paper is to assess how change in climate variables is affecting crop yield, non-climatic factors remain constant would be the assumption for this paper.

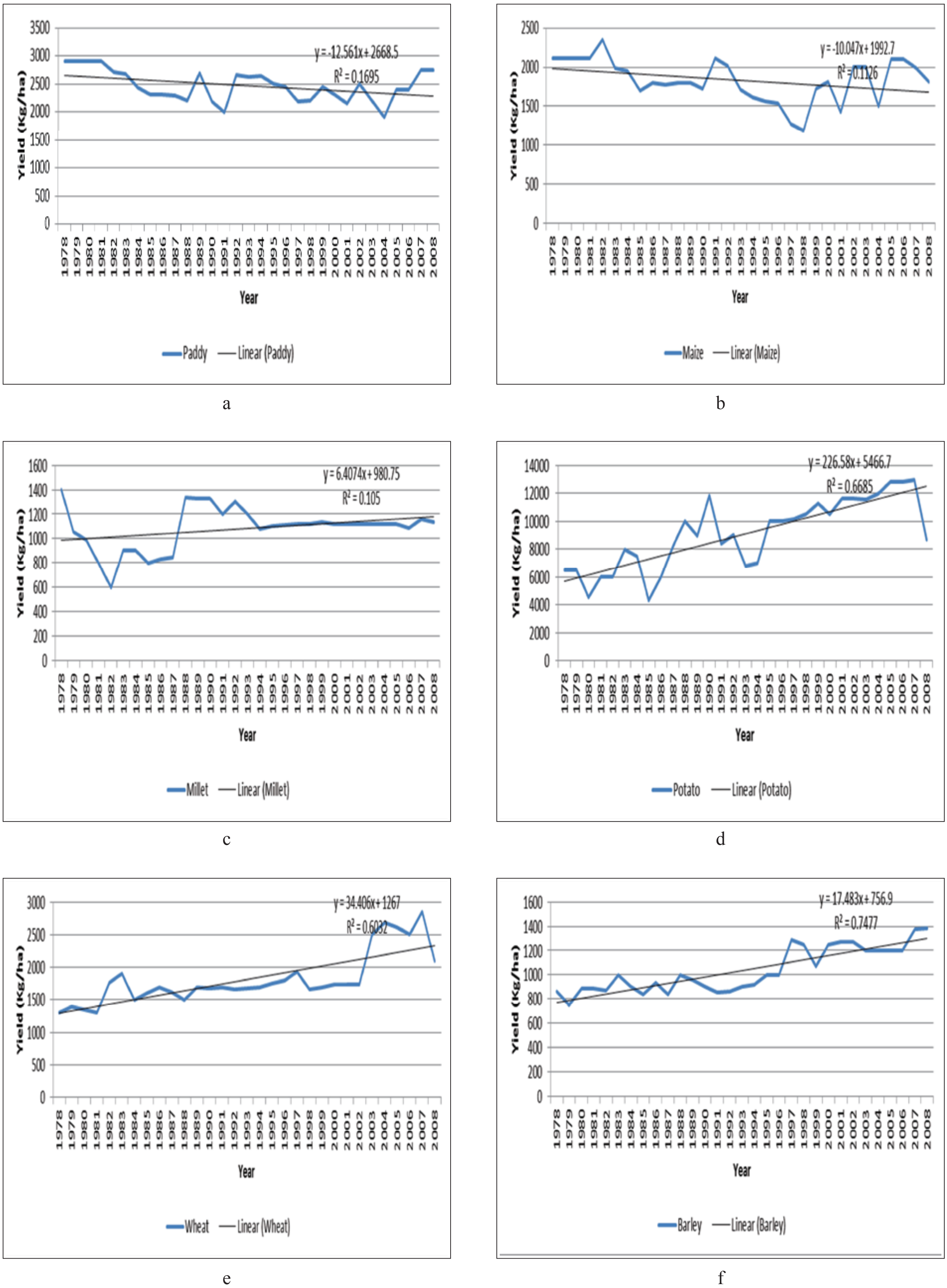

Figure 5. (a, b, c, d, e and f). Food crops yield trend in Makwanpur from 1978 to 2008

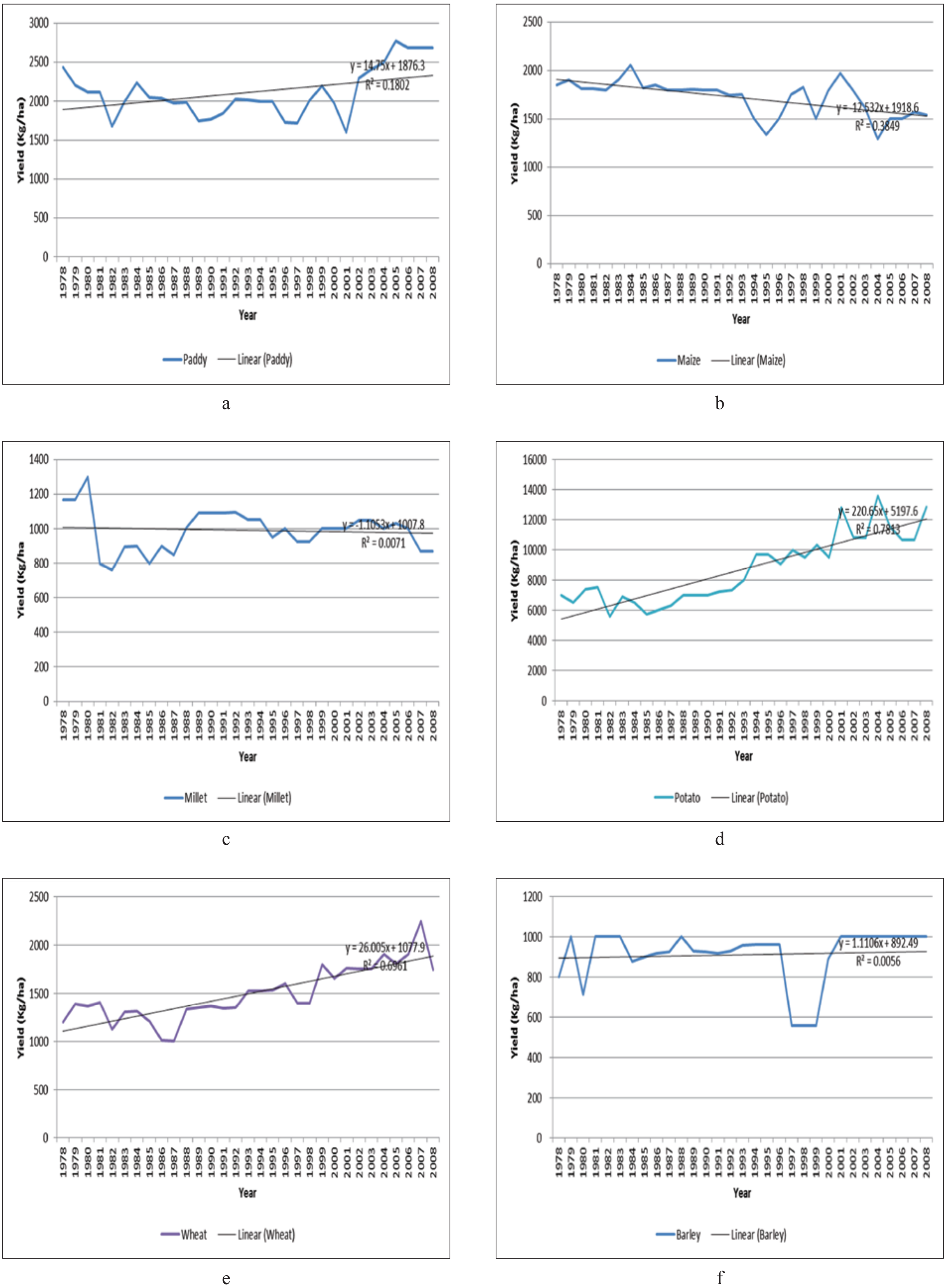

Figure 6. (a, b, c, d, e and f). Food crops yield trend in Ilam from 1978 to 2008

3.3 Effect of climate change on yield of major food crops of Nepal

3.3.1 Effect of climate change on yield of major food crops of Nepal in Makwanpur

The effect of climate change on the yield of major crops of Nepal was analyzed using the multiple regression analysis given by Nicholls (1997). Detrending was done so that the management practices can be removed and only the effect of climatic variables on these crops can be calculated.

Table 1. Effect of climatic variables on yield of major food crops in Makwanpur

Crops	Max temp coefficient	P value	Min temp coefficient	P value	Rainfall coefficient	P value	Change in Yield
Maize	-27.88	0.70	-129.83	0.01***	-0.00	0.99	-311.63
Paddy	81.18	0.29	-93.11	0.05**	0.69	0.24	214.54
Wheat	17.46	0.72	-63.43	0.20	3.27	0.27	-331.06
Millet	-60.44	0.16	23.81	0.36	-0.00	0.99	-124.93
Potato	-666.78	0.21	5.97	0.98	1.97	0.62	-4603.67
Barley	-9.57	0.60	-19.25	0.30	-0.37	0.74	-197.70

*** 1% level of significance, ** 5% level of significance

In Table 1, except paddy, climate change has adversely affected yield of all other major food crops. Climate change has positive impact on yield of paddy where it increased by 214.54 kg/ha from 1978 to 2008 whereas yield of maize, wheat, millet, potato and barley decreased by -311.63 kg/ha, -331.06 kg/ha, -124.93 kg/ha, -4603.67 kg/ha and -197.70 kg/ha respectively. While analysing the effect of different climatic variables on yield of crops it was seen that maximum temperature have positive relationship with yield of paddy and wheat at 81.18 and 17.46 respectively, whereas yield of maize, millet, potato and barley have negative relationships with coefficient of -27.88, -60.44, -666.783 and -9.57 respectively. Further, minimum temperature has negative relationship with yield of maize, paddy, wheat and barley with coefficient of -129.83, -93.11, -63.43 and -19.25 respectively and has only significant relationship with yield of maize at 1% level of significance and yield of paddy at 5% level of significance but other crops does not have significant relationship. Also, analysis shows that minimum temperature has positive relationship with the yield of millet and potato having coefficient of 23.81 and 5.97 respectively. Analysis also shows that the rainfall has negative relationship with yield of maize, millet and barley with coefficient of -0.0001, -0.001, and -0.373 respectively but are not significant. Though the majority of the coefficient did not have significant p-value, this analysis showed the direction in which climate change is having effect on the yield of major food crops of Nepal. Moreover, these coefficients will be utilized later to quantify the actual impact of climate change on yield of the food crops.

3.3.2 Effect of climate change on yield of major food crops of Nepal in Ilam district

Table 2 shows the impact of climatic variables on the yield of major food crops of Nepal in Ilam district. Climate change had the positive impact on maize, potato and barley in increasing the yield by 28.59 kg/ha, 508.37 kg/ha and 24.74 kg/ha respectively whereas paddy, wheat, and millet decreased by -246.961 kg/ha, -136.251 ha/kg and -5.399 kg/ha respectively from 1978 to 2008. The maximum temperature had positive relationship with yield of maize and wheat having coefficient of 89.46 and 24.38 respectively. Only maize had significant p-value with maximum temperature at 5% level of significance whereas in other crops there was no significant p-value. The minimum temperature had negative relationship with yield of potato and barley having

Table 2. Effect of climate change on yield of major food crops of Nepal in Ilam

Crops	Max temp coefficient	P value	Min temp coefficient	P value	Rainfall coefficient	P value	Change in Yield
Maize	89.46	0.04**	12.45	0.66	0.07	0.84	28.59
Paddy	-60.79	0.26	54.85	0.14	1.18	0.01***	-246.96
Wheat	24.38	0.70	51.82	0.25	2.93	0.061*	-136.25
Millet	-19.58	0.56	9.58	0.67	-0.07	0.80	-5.40
Potato	-88.23	0.88	-147.76	0.71	-3.11	0.50	508.37
Barley	-17.03	0.75	-2.30	0.95	0.65	0.61	24.74

* 1% level of significance, ** 5% level of significance, *** 10% level of significance

coefficient of -147.76 and -2.30 respectively; whereas yield of maize, paddy, wheat and millet had positive relationship with coefficient of 12.45, 54.85, 51.82, and 9.58 respectively, but none had significant p-value. Furthermore, rainfall had negative relationship with yield of millet and potato having coefficient of -0.07 and -3.11 respectively while yield of other crops maize, paddy, wheat and barley had positive relationship with coefficient of 0.07, 1.18, 2.93 and 0.65 respectively. Only yield of paddy and wheat have significant relationship with rainfall at 1% level of significance and 10% level of significance respectively while yield of other crops did not have any significant p-value. Though climatic variables did not have any significant relationship with the change in yield of major food crops in both the districts, the analysis shows the direction in which the climate change is having effect on major food crops of Nepal in both districts.

4. Conclusion

The trend analysis of climatic variables in both the districts shows that the summer maximum and minimum temperature of Makwanpur district is increasing with the coefficient of 0.085 and 0.060 and winter maximum and minimum temperature was increasing with coefficient of 0.136 and 0.085 showing increasing trend which is higher in winter than summer. The summer rainfall in Makwanpur district was found to be increasing with coefficient of 4.57 though it was quite erratic, while winter temperature was decreasing slightly with coefficient of -0.13. In Ilam district, the summer maximum temperature was increasing with coefficient of 0.05, but summer minimum temperature was decreasing with coefficient of -0.037. Similarly, the winter maximum temperature was increasing with coefficient of 0.06 and minimum temperature was decreasing with coefficient of -0.03. The increase in maximum temperature and decrease in minimum temperature indicate that days are becoming warmer and nights cooler, and also indicate that the weather in the area are becoming more extreme. Further, summer and winter rainfall of Ilam district was in decreasing trend with coefficient of -0.44 and -0.27 respectively, and also erratic. This erratic and inter-annual variation in rainfall has effect on some years having high rainfall and some years being drought year. This change in the climatic variables have effect on the yield of the food crops in both districts with some crops showing steady increase while some are in decreasing trend.

So, the yield trend was analysed to see how yield of major food crops of Nepal in Makwanpur and Ilam district are changing. The simple regression analysis showed that in Makwanpur district, yield of paddy and maize is decreasing with coefficient of -12.56 and -10.04 respectively while millet, potato, wheat and barley are increasing with coefficient of 6.40, 226.58, 34.40 and 17.48 respectively. The decrease in yield of paddy can be attributed to drought and also management practices not improving over the course of time. Also, there was sharp increase in the yield of potato which is mainly attributed to the new varieties of potato and the use of fertilizers and pesticides. In the case of Ilam district the yield of maize and millet was found to be in decreasing trend with coefficient of -12.53 and -1.10 respectively while paddy, potato, wheat and barley were found to be in increasing trend with coefficient of 14.75, 220.65, 26.00 and 1.11 respectively. Also in Ilam district, potato was found to be increasing sharply which can also be attributed to the use of high yielding varieties, fertilizers and pesticides, and also to the development of potato as a cash crop in the area.

As, yield of the food crops in both the districts were in both direction to see the effect of climatic variables on yield was analysed. As there were limitations of availability of management data for the period of 30 years, the multiple regression analysis as given by Nicholls (1997) which detrends the managerial aspect was used. The analysis showed that in Makwanpur district, the net effect of climatic variables had negative relationship with yield of all the major food crops of Nepal except for paddy. While in the case of Ilam district, net effect of climatic variables had negative relationship on yield of all the major food crops except maize and potato. The decrease in yield of paddy in Ilam district can be attributed to decrease in rainfall. Only the minimum temperature had significant relationship with yield of maize and paddy in Makwanpur district. Similarly, maximum temperature had significant relationship with maize, and rainfall had significant relationship with paddy and wheat in Ilam district. Though the majority of the climatic variables did not have significant p-value, but this analysis showed the direction in which climate change has effect. Finally, despite the suppression of yield by the climatic variables in some of the cases, most of these food crops overcome such suppression, but crops like paddy, maize and millet were not able to overcome such depression leading to decrease in overall yield emphasizing the special attention is needed to overcome adverse effect of climate change. Also, there is need for future researches regarding the effect of climate change on crop productivity that incorporates both the climatic factors as well as managerial factors to better understand it.

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Appendix 1. Summary output of multiple regression analysis of food crops in Makwanpur district

Maize

Regression Statistics	
Multiple R	0.509194
R Square	0.259279
Adjusted R Square	0.173811
Standard Error	240.7288
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	527402.5	175800.8	3.033645	0.047112
Residual	26	1506709	57950.36		
Total	29	2034112			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	5.194473	45.89316	0.113186	0.910752	-89.1403	99.52921	-89.1403	99.52921
Max temp.	-27.8836	71.94113	-0.38759	0.701475	-175.761	119.9935	-175.761	119.9935
Min temp.	-129.826	43.5157	-2.98343	0.006127	-219.274	-40.3783	-219.274	-40.3783
rainfall	-0.00013	0.54934	-0.00024	0.999813	-1.12931	1.129053	-1.12931	1.129053

Paddy

Regression Statistics	
Multiple R	0.423194
R Square	0.179093
Adjusted R Square	0.084373
Standard Error	249.2048
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	352266.9	117422.3	1.890766	0.155944
Residual	26	1614678	62103.02		
Total	29	1966945			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-10.2099	47.50904	-0.2149	0.831519	-107.866	87.44634	-107.866	87.44634
Max temp.	81.17635	74.47415	1.089994	0.285715	-71.9074	234.2602	-71.9074	234.2602
Min temp.	-93.1087	45.04787	-2.06688	0.048837	-185.706	-0.51145	-185.706	-0.51145
rainfall	0.690386	0.568682	1.214012	0.235656	-0.47856	1.859328	-0.47856	1.859328

Wheat

Regression Statistics	
Multiple R	0.381763
R Square	0.145743
Adjusted R Square	0.047175
Standard Error	248.0629
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	272957.4	90985.81	1.478598	0.243472
Residual	26	1599915	61535.19		
Total	29	1872872			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	34.05348	45.67599	0.745544	0.46263	-59.8349	127.9418	-59.8349	127.9418
Max	17.45952	47.5718	0.367014	0.716579	-80.3257	115.2448	-80.3257	115.2448
Min	-63.4298	48.22712	-1.31523	0.199914	-162.562	35.70246	-162.562	35.70246
rainfall	3.266209	2.912338	1.121508	0.272323	-2.72019	9.252605	-2.72019	9.252605

Millet

Regression Statistics	
Multiple R	0.362185
R Square	0.131178
Adjusted R Square	0.030929
Standard Error	140.8759
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	77906.88	25968.96	1.308522	0.292802
Residual	26	515996.8	19846.03		
Total	29	593903.7			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1.58127	26.85695	0.058877	0.9535	-53.624	56.78652	-53.624	56.78652
Max	-60.4382	42.10038	-1.43557	0.163046	-146.977	26.1004	-146.977	26.1004
Min	23.80914	25.46565	0.934951	0.358416	-28.5362	76.15453	-28.5362	76.15453
rainfall	-0.00153	0.321477	-0.00475	0.996244	-0.66233	0.659277	-0.66233	0.659277

Potato

Regression Statistics	
Multiple R	0.353853
R Square	0.125212
Adjusted R Square	0.024275
Standard Error	1734.716
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	11198837	3732946	1.240495	0.315202
Residual	26	78240224	3009239		
Total	29	89439062			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	218.0134	330.7107	0.659227	0.515547	-461.772	897.799	-461.772	897.799
Max	-666.783	518.415	-1.2862	0.209711	-1732.4	398.834	-1732.4	398.834
Min	5.972661	313.5785	0.019047	0.984949	-638.597	650.5425	-638.597	650.5425
rainfall	1.969473	3.958596	0.497518	0.623005	-6.16754	10.10648	-6.16754	10.10648

Barley

Regression Statistics	
Multiple R	0.477751
R Square	0.228246
Adjusted R Square	0.139198
Standard Error	93.68811
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	67494.4	22498.13	2.563171	0.076461
Residual	26	228214	8777.462		
Total	29	295708.4			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	21.37386	17.25086	1.239003	0.226413	-14.0858	56.8335	-14.0858	56.8335
Max	-9.56627	17.96686	-0.53244	0.598943	-46.4977	27.36515	-46.4977	27.36515
Min	-19.2501	18.21437	-1.05687	0.300295	-56.6903	18.19004	-56.6903	18.19004
rainfall	-0.37359	1.099928	-0.33965	0.736847	-2.63453	1.887343	-2.63453	1.887343

Appendix 2. Summary output of multiple regression analysis of food crops in Ilam District

Maize

Regression Statistics	
Multiple R	0.438501
R Square	0.192283
Adjusted R Square	0.099085
Standard Error	151.4379
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	141946.4	47315.46	2.063164	0.129638
Residual	26	596269.5	22933.44		
Total	29	738215.9			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-14.2685	27.69926	-0.51512	0.610821	-71.2051	42.66818	-71.2051	42.66818
Max	89.46433	40.90741	2.186996	0.037932	5.37794	173.5507	5.37794	173.5507
Min	12.45259	28.04697	0.44399	0.660723	-45.1988	70.10397	-45.1988	70.10397
rainfall	0.067827	0.327703	0.206975	0.837642	-0.60578	0.741431	-0.60578	0.741431

Paddy

Regression Statistics	
Multiple R	0.594674
R Square	0.353637
Adjusted R Square	0.279057
Standard Error	193.7121
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	533788.1	177929.4	4.7417	0.009082
Residual	26	975633.8	37524.38		
Total	29	1509422			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	9.958912	35.43156	0.281075	0.780878	-62.8717	82.78952	-62.8717	82.78952
Max	-60.7934	52.32679	-1.1618	0.255871	-168.353	46.76591	-168.353	46.76591
Min	54.84592	35.87634	1.528749	0.138403	-18.899	128.5908	-18.899	128.5908
rainfall	1.182058	0.419183	2.819914	0.00907	0.320416	2.0437	0.320416	2.0437

Wheat

Regression Statistics	
Multiple R	0.526786
R Square	0.277503
Adjusted R Square	0.194138
Standard Error	164.455
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	270084.6	90028.2	3.328775	0.035004
Residual	26	703181.5	27045.44		
Total	29	973266.1			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	21.89545	30.15941	0.725991	0.47433	-40.0981	83.88902	-40.0981	83.88902
Max	24.38479	63.65766	0.383061	0.704788	-106.465	155.235	-106.465	155.235
Min	51.82087	44.21011	1.17215	0.251766	-39.0543	142.696	-39.0543	142.696
rainfall	2.92571	1.496761	1.954694	0.061451	-0.15093	6.002345	-0.15093	6.002345

Millet

Regression Statistics	
Multiple R	0.130083
R Square	0.016922
Adjusted R Square	-0.09651
Standard Error	121.3192
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	6586.986	2195.662	0.149178	0.929278
Residual	26	382677.4	14718.36		
Total	29	389264.3			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-9.20824	22.1903	-0.41497	0.681571	-54.8211	36.40458	-54.8211	36.40458
Max	-19.5824	32.77156	-0.59754	0.555314	-86.9453	47.78049	-86.9453	47.78049
Min	9.576991	22.46886	0.426234	0.673446	-36.6084	55.7624	-36.6084	55.7624
rainfall	-0.06882	0.262528	-0.26213	0.79529	-0.60845	0.470819	-0.60845	0.470819

Potato

Regression Statistics	
Multiple R	0.152617
R Square	0.023292
Adjusted R Square	-0.08941
Standard Error	2115.52
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	2774893	924964.3	0.206676	0.890841
Residual	26	1.16E+08	4475424		
Total	29	1.19E+08			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	445.0426	386.9462	1.150141	0.260555	-350.337	1240.422	-350.337	1240.422
Max	-88.2299	571.4582	-0.15439	0.878491	-1262.88	1086.419	-1262.88	1086.419
Min	-147.758	391.8036	-0.37712	0.709143	-953.122	657.6057	-953.122	657.6057
rainfall	-3.11195	4.577871	-0.67978	0.502652	-12.5219	6.298001	-12.5219	6.298001

Barley

Regression Statistics	
Multiple R	0.182352
R Square	0.033252
Adjusted R Square	-0.0783
Standard Error	138.7234
Observations	30

ANOVA

	df	SS	MS	F	Significance F
Regression	3	17210.07	5736.692	0.2981	0.826427
Residual	26	500348.4	19244.17		
Total	29	517558.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	7.388726	25.44049	0.290432	0.77379	-44.9049	59.6824	-44.9049	59.6824
Max	-17.0328	53.69739	-0.3172	0.753625	-127.409	93.34378	-127.409	93.34378
Min	-2.29884	37.29273	-0.06164	0.951318	-78.9551	74.35745	-78.9551	74.35745
rainfall	0.649637	1.262568	0.514536	0.611224	-1.94561	3.244884	-1.94561	3.244884