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Effect of Climate Change on Rice Farming and its Coping Strategies

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Abstract

Rice is staple crop in Nepal and various factors play an important role in the fluctuating production of rice. By assuming the decrease in yield is due to change in various parameters of climate. Winds, droughts, rainfall, hailstones and erosion were the basic climatic factors undertaken for the study. Result depicted that ninety four percent of the respondents reported that they have been facing severe changes in climate as compared to 10 years before. Drought was the major parameter in effect of the rice farming. Rice has been replaced by maize for alternatives. However, the consumption pattern shows 97 percent of peoples prefer to have rice as a major food. Therefore, drought tolerant varieties such as Sukkha-1, Sukkha-2, Sukkha-3, Khumal-10 and Khumal-13 should be introduced in the study areas. Also, SRI (System of Rice Intensification) could be other possibilities to cope with the climate changes.

Introduction

Climate is long-term manifested in many instances of weather (Kempton, 1991). Climatic factors such as precipitation, temperature, humidity, sunlight intensity has greater influences in rice production (Mallik, 1982). The causes of climate changes are due to natural and anthropogenic changes. Increase in global temperature for the millennium is estimated to be 1.1 to 6.4°C, however, the best estimation ranges extends from 1.8 to 4.0°C (Bharadwaj et al., 2009). The warming is expected to increase in average temperature of the earth over the next few decades of as much as 0.5 to 1.0°C per decade. Developing countries will be faced doubly hard by global warming. Both the

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geographical location of developing countries and their ability to cope with environment decline more seriously and sooner than the richer nations of the mid and higher altitudes (UNU Monitor, 1991). Agriculture sector is not escaped with the effect of climate change.

To the great extent, ultimate effect of climate change on hunger and agriculture will be depending upon of adaptive responses on several scales. Small change in climate will be readily accommodated by adjusting agricultural practices such as cropping pattern, changing rice varieties, use of quality seeds, irrigation, soil conservation, timely agronomical operation, land use pattern, and crop varieties and types (Downing, 1991). Responses to the more general question of how to respond to the threat of global warming can be divided into three characteristics positions: 'prevention', 'adaptation' and 'sustainable development'. These divisions exist in all countries (Rayner, 1993). Adaptation to the climate is relevant to both long term global climate change and current variability in climate conditions. In the case of global climate change, adaptation is more essential elements of any estimate of impacts and as one of the possible response options. For current variability, an improved understanding of individual and societal adaptation is important. It not only provides insights for estimating future adjustments, but also helps address current problems of sustainable development in uncertain environments (Smithers & Smit, 1997).

Rice (*Oryza sativa*) is a staple crop in Nepal. Two third of the GNP is supported by rice in Nepal. In Nepal Rice has been cultivated from 60 masl in Jhapa to 3050 masl in Jumla, which is the highest rice growing region in the World (Hamada, 1956).

The role of edaphic factors such as temperature, soil moisture content, humidity, dew, frost, rainfall, wind, fog, and hailstone has direct effect on rice cultivation. Fluctuation in these factors has effect on penology of rice. Wind has direct impact on transpiration, intake of carbon dioxide and causing several types of mechanical damage (Singh & Murty 2009). Gentle wind is better for rice cultivation. Clear sunny weather in ripening and humid weather in vegetative phase is desirable for rice crop. Temperature, relative humidity and rainfall are the most important factors. The minimum and maximum temperature for germination of rice is 10-12°C and 36-38°C respectively, whereas 30-32°C is optimum temperature for germination (Singh & Murty 2009). Moderate temperature require for rice is 12-14°C. Beside, this crop requires 1400-1800 mm water. Relative humidity of 60-80 percent is said to be optimum for rice growth (Sikkim, 2011). Rai (2009) has mentioned that in rice farming, increase in minimum temperature by 1°C (18-19°C) caused to decrease yield at the rate of 0.71 t/ha and increase of 1°C (22-23°C) had decrement of 0.41 t/ha. Similarly, he mentioned that 2°C increases in mean air temperature decreases yield by 0.75 t/ha in high yield areas and by 0.06 t/ha in low yield areas. Therefore, effect of climate change, especially in fluctuation of temperature has major impact on rice production.

Rice is more popular in Hilly Region of Nepal where farmers grow in low land holdings with low production compared to Terai region. Low production is basically due to lack of optimum use of inputs including suitable cultivars. Besides these factors, now the emerging issues of climate change could also be the causes of low production. Therefore, it is extremely important to know the seasonal variations and its effect in the rice farming. Thus, the study relates to effect of climate change in rice production, its coping strategies, and to explore the ideas related to the scenario of hills, *tars* (plain area in the hilly region) and river basin of study sites. It is expected that the study can reap an ideas for agricultural forecast on implementing policies.

Materials and Methods

Site Selection and Description

Kavre district of Nepal is 35 Km east from Kathmandu. The sloppy hills, valleys/river basin and plateau covered 64, 13 and 23 percent of the district. Eight VDCs of Kavre district namely Mangaltar, Bhakunde Besi, Khanal Thok, Daraune Pokhari, Fulbari, Bhim Khori, Nitin Kote, Chapar Bari were the selected sites. In 2006-2009, the district was in national media focused on agricultural commodity, mainly rice which has been affected by extreme drought. Therefore, forty household of the drought prone area were surveyed felt to set strategies to cope the problems. Mainly, drought, phenological stages of rice, pest problems and rice varieties were undertaken on the study.

Data Collection

Besides secondary information in different forms, primary information was collected employing focused group discussion (FGD), household survey in the selected farmers' households[6], and participatory rapid appraisal (PRA) methods. Due to unavailability of hydrology and meteorology station in the local areas, no scientific data regarding rainfall, moisture level, humidity, wind, hailstones and temperature was able to capture. Thus, while comparing before and present climatic effect in rice farming, memory recall of the respondents was the basic approaches followed which may not have captured the accurate reality. Descriptive methods were mostly followed in this study. Farmers were selected randomly on the priority of rice cultivation.

Results and Discussion

Cereals Production

Generally, farmers in the area produce three crops in a year. The majority of respondents (17.6%) followed 'rice, maize, vegetables' and 'rice, wheat, maize, vegetables' cropping pattern. Rice, like in other location of Nepal, was found as the major cereal in Kavre district, followed by maize and wheat respectively. Nearly 51.804 quintal/hector of rice production per household was evaluated in the study areas. Standard deviation was found 23.402 which was very high indicating higher variation of rice production among farmers (Table 1).

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6 Farmers were selected randomly on the priority of rice cultivation.

Table 1: Cereals Production per Hectare

Cereals production	Average (Qnt/ha)
Rice production	51.804 (23.402)
Wheat production	35
Maize production	40.604

Note: Figure in parenthesis indicates standard deviation of rice production.
Source: Household Survey, 2010/11.

Average rice cultivated area in the study areas was found 0.321 ha per household. Standard deviation was found 0.417 indicating higher variation of landholdings.

Condition of Climate Change

Ninety four percent of the respondents reported that they have been facing severe changes in climate as compared to 10 years before. While only 6 percent of the respondents reported no changes in climate felt at all. Winds, drought, rainfall, hailstones and erosion were the basic climatic factors undertaken for the study. While comparing present and ten years back climatic situation, majority of respondents reported declining trend of rainfall (95% of respondents) and increasing trend of drought (84.6%). This changing trend of moisture according to the respondents could be the reason behind poor phenological development ultimately leading to low rice production. Soil erosion, especially landslides in the study district was found minimum in present days. Seventy one percent of the respondents reported landslides has declined as a result of minimum rainfall. However, wind and hailstone occurrence in present situation was found rapidly fluctuating. Light wind is favorable for rice farming. It was somehow positive that 95 percent of respondents reported minimum wind these days. Sixty percent of the respondents has reported maximum hailstone occurrence with heavy short duration rainfall with serious damage in crops with shattering and lodging (Table 2).

Table 2: Farmers Perception Regarding Climatic Condition before 10 Years and Now

Climatic Conditions	Respondents view regarding climatic conditions before 10 years			Respondents view regarding climatic conditions nowadays		
	Parameters (% of Respondents)					
	Maximum	Moderate	Minimum	Maximum	Moderate	Minimum
Drought	5	15	80	84.6*	15.4	-
Wind	45.5	54.5*	-	-	5	95
Rainfall	94.7*	5.3	-	66.7	-	33.3
Hailstone	37.5	50	12.5	60	-	40
Erosion	62.5	25	12.5		28.6	71.4

* Denotes for the maximum *Effect in Rice Phenology*.
Source: Household Survey, 2010/11.

Temperature has great role in rice production from the seedling stages to ripening phase. Table 3 shows appropriate temperature for different stages of rice crop.

Table 3: Critical Temperature for Rice Crops for Different Growth Stages

Growth	Critical Temperature (°C)		
	Low	High	Optimum
Germination	16-19	45	18-40
Seedling emergence and establishment	12-35	35	25-30
Rooting	16	35	25-28
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Panicle initiation	15	-	-
Panicle differentiation	15-20	30	-
Anthesis	22	35-36	30-33
Ripening	12-18	>30	20-29

Source: Singh and Murty, 2009.

Rice Tillering

Farmers from the selected household have given their views regarding rice tillering before and now a days differently. Among them 54 percent viewed, it was good as compared to the previous years where 46 percent have mentioned poor tillering only due to prevailing drought, hailstone and insect pest infestation as well.

Flowering

Ten years back nearly 90 percent farmers were quite unaware about the flowering situation of rice. However, at present, 50 percent and 33.3 percent of the respondents have explained early and late flowering pattern respectively where 17 percent opined no any change in the last one decade (Table 4). The variation in flowering pattern at present may be due to phelonogical variation among rice varieties in farmer's field. Besides this, variation of sowing time as well as effect of rainfall and temperature in rice may have also lead to fluctuation in flowering pattern.

Table 4: Perceptions of the Farmers on Flowering Pattern before 10 Years and Now (in %)

Flowering Pattern	10 Years Back		Now a Days	
	Flowering	No ideas	Flowering	No ideas
Early flowering	10.8	89.2	50	-
Late flowering	-	-	33.3	-
No changes (same as before)	-	-	16.7	-

Source: Household Survey, 2010/11.

Maturity

Perception about the change in maturity stage was gathered to compare between before ten years and now. In the study district, before ten years, only 5.4 percent of the respondents reported that rice crop mature quite earlier. On the contrary to previous scenario, heavy fluctuating in early maturity of rice crops has been reported by 92.3 percent, and only 7.8 percent respondent informed that they did not experienced any change during the study period. The early maturity is associated only with the wide number of rice varieties grown in the local area. Khumal-4, Taichung, Sabitri and Mansuli were the major varieties grown. Apart from these, maximum drought may have changed sowing period of the rice. In other words, it may be due to the effect of climate change.

Occurrence of Diseases and Insect/Pests

As compared to previous context, occurrence of disease and pest has found maximum. Four-fifths respondents have stated that no disease was occurred in the past. In case of occurrence of pest nearly 90 percent farmers could not replied the level of infection. However, at present 95.8 percent and 96.2 percent of the respondents reported maximum infestation of disease and pest respectively (Table 5). These may be due to unsystematic use of insecticides and pesticides leading to the possible reasons of insect pest outburst due to effect of climate change.

Table 5: Occurrence of Diseases and Insect/Pests (in %)

Degree of Infection	10 Years Back		Now a Days	
	Occurrence Disease	Occurrence Pest	Occurrence Disease	Occurrence Pest
Maximum infestations	-	-	95.8	96.2
Moderate infestations	20.0	-	-	-
No infestations	80.0	10.8	4.2	3.8
No ideas	-	89.2	-	-

Source: Field Survey, 2010/11.

Farmer's Perception in Crop Loss

Farmers perceived differently (loss due to insects', diseases, pest and others) on loss of rice crop during the study period. Moderate loss due to insects was perceived by 45.5 percent of the farmers where the same proportion perceived maximum loss. Thirty percent each of the respondents have reported moderate and maximum losses by the diseases while 20 percent of the respondents have reported failure of crops by the diseases infestation. Similarly, 75 percent of the respondents mentioned moderate loss by pest while 30, 36 and 34 percent of the respondents respectively have mentioned minimum, moderate and maximum post-harvest losses (Table 6). The post-harvest losses may be due to poor phenotype of rice; for instances, shattering and over lodging creating difficulties in harvesting. Other post harvest losses are however not considered in the study. The favorable temperature of *Pyricularia oryzae* (causal organism of blast) is 24-28°C; *Xanthomonas campesteris* pv. *oryzae* (causal organism of leaf blight) is 22-26°C (Rangaswami, 1998). Overall, effect of the climate change might have created favorable ecosystem for rice pest in the study area of Kavre districts.

Table 6: Farmer's Perception on Rice Crop Losses Due to Different Factors

Level of losses	Farmer's perception on insects' loss (%)	Farmer's perceptions on diseases losses (%)	Farmer's perception on pest loss (%)	Other loss (Shattering + Post harvest losses) (%)
Minimum (<10%)	-	20.0	25	30
Moderate (10-30%)	45.5	30.0	75	36
Maximum (30-50%)	45.5	30.0	-	34
Severe (50-80%)	9.1	-	-	-
Failure of crops (>80%)	-	20.0	-	-

Source: Field Survey, 2010/11.

Among the common damaging insects available in rice farm, ear head cutting caterpillar is considered the most prominent insect that produced more damage. Beside this butterfly, rice gundhi bug are other major insects responsible to damage rice (Table 7). The farmers further reported that impact of climate change and over use of insecticides may have introduced new insects with higher resistances against insecticides.

Table 7: Common Damaging Rice Insects

Rice insects	Percentage
Rice gundhi bug (*Leptocorsia varicornis*)	15
Gundhi bug+ Ear head cutting caterpillar	12
Ear head cutting caterpillar (*Mythimna separate*)	38
Butterfly	25
Leaf and Plant hoppers Green leaf hopper (*Nephotettix virescens*) Brown plant hopper (*Nilparvata bugens*)	10

Source: Field Survey, 2010/11.

Bacterial blight infestations have been higher in Eastern Terai region of Nepal. Moreover, blast incidences are high in upland rice than in lowland rice. The disease is more common in hilly region of Nepal. High rainfall, high humidity and cool night favor the incidence of this disease (Mallik, 1982). In these days, bacterial bight *(Pyricularai oryzae)* with (33.3%) has been prominent to damage reported in the study district which is also located in hilly region. Zinc deficiency, *Khaira* diseases, leaf blight are other common diseases destroying rice farm (Table 8).

Table 8: Common Damaging Rice Diseases

Rice diseases	Percentage
Blast (*Pyricularai oryzae*)	33.3
Leaf blight (*Xanthomonas oryzae*)	22.2
Blast + Blight	11.1
Others(Zinc deficiency, *Khaira* diseases)	33.3

Source: Field Survey, 2010/11.

It has been found that the outbreak of insect pest and rice crop diseases in the study areas are in devastating ways as compared to before.

Plantation of Alternate Cereals

Rice in Nepal is mostly grown in rainy season. As an impact on climate change, rice plantation has been found replaced by few farmers. In the critical situation such as in drought period, minimum number of respondents has reported that they followed coping strategies for food security. Only 17.6 percent and 11.8 percent of the respondents followed maize and vegetables plantation respectively after harvesting rice. Such coping strategies have somehow helped to maintain household food security. While due to lack of knowledge in farming system, 41.2 percent of the farmers have remained land fallow and 29.4 percent planted rice even in unfavorable climatic period, as they have no other options (Table 9). These have ultimately created food insecurity in the study region which has implications on serious problem in socio-economic sectors such as expanding fragile livelihood, shift in occupation and migration. Thus, coping strategies such as alternatives crop plantation, rainwater harvesting, irrigation canals, and plantation of stress/drought tolerance varieties of rice could be the possible solutions to overcome from the impact of climate change. As the 97 percent of the respondents consumed rice crops for their daily diets, it shows the need for farmers to make aware about the holistic approach of technological strategies in support of government to cope against drought and other climatic variations.

Table 9: Plantation instead of rice

Plantation	Percentage
No plantation of other crops	41.2
Maize plantation	17.6
Vegetables cultivation	11.8
No other options (rice plantation)	29.4

Source: Field Survey, 2010/11.

Change in Rice Varieties

The major varieties grown in the study areas were Khumal- 4 (32.4%), Taichung (21.5%), Sabitri (13.5%), Mansuli (10.4%). Nearly seventy two percent of the farmers were found to be changing rice varieties during twenty years of rice farming, whereas 28 percent of respondents have been planting same traditional varieties over the periods. Decrease in rice production as consequences of drought and increasing in insect pest infestation have had lead farmers to change varieties. Beside these, farmers' demands are generally focused on distinctive phenotypes of rice, such as drought tolerance varieties, insect pest resistance varieties, lodging tolerances varieties as well as short duration rice varieties with high production (Table 10). The effect of climate change could be the reason behind farmer's choice in varieties changes. Farmers basically preferred early maturing varieties to overcome the risk of drought and hailstone.

Table 10: Reasons behind Varieties Change

Reasons	Respondents (percent)
More production	51.0
Drought	9.0
For early maturity of the crops	14.0
Lodging tolerance	8.5
High price of the seeds with low agronomic traits	3.3
Good eating quality	7.1
No change	7.1

Source: Field Survey, 2010/11.

Most of the farmers (65.4%) preferred to change rice varieties at the interval of 1-5 years, while 7.7 percent of them had never changed. It has been revealed that the varieties changing trend has come into pace in these recent decades in hilly region of Nepal as well. This could be due to increasing marketing and extension of rice varieties in rural areas as consequences of scientific outcome viz. release of rice varieties which can cope against adverse climatic changes as well as can overcome the insect pest damages.

System Rice Intensification (SRI) as a Coping Strategy against Drought

Cultivating a single kilo of rice requires 5,000 liters of water in case of India. If the SRI were to be applied on all this land, it would be able to cut water requirement for paddy by 50 percent and simultaneously boost rice production by 50 percent (SANDRP, 2011). Likewise, in the case of Kavre, 2829 Kg/ha of rice yield has been recorded (MOAC, 2010). With respect to situation of India, in the case of Kavre, 14145000 liter water is needed per year as the area remaining constant. If the 50 percent of water intake could be reduced by SRI only 7072500 liter water is sufficient to produce the same quantity of rice. Therefore, introducing of SRI could be a good coping strategy for sustainable rice production in less water available situation.

Constraints

Unavailability of quality seeds, expensive seeds, late maturity period and prevailing drought were the major constraints in rice farming. Twenty one percent of the respondents mentioned that the drought and expensive seeds were the major constraints in rice farming in the study sites. On consultation of rice breeders, NARC, recently released varieties such as Sukkha-1, Sukkha-2, and Sukkha-3 are recommended to grow in altitude up to 1100 masl. These varieties can cope against drought in critical stages in rice phenology such as in seedling, tillering and flowering stages. Beside this, other recently released varieties by NARC, namely Khumal-10 and Khumal-13 are suitable in altitude above 800 masl to cope against droughts.

Conclusion and Suggestions

In the study area of Kavre district, several climatic changing scenarios especially drought and temperature increment with negative impact on rice farming has been documented by memory recalling approach of the respondents. Changing climatic scenario as compared to previous decades has effect in tillering, fluctuating early and late maturity periods with differing flowering durations have been reported. Besides these, impact of climate change as well as due to increasing use of insecticides and pesticides may have created favorable ecosystem for diseases and pest for rice crop in the study district. Insects such as rice gundhi bugs, ear head cutting caterpillar, leaf hoppers and diseases such as leaf blast, blight has created even a total crop failure in few households. Lack of awareness as well as extension work on rice seed dissemination has lead farmers to choose inappropriate rice varieties unfavorable to study sites which ultimately may have lead to low productions.

Farmers should be encourage in plantation of high yielding short duration varieties with stress tolerance, lodging tolerance, pest/diseases tolerances as well as with varieties richness in traits such as good eating quality. Water harvesting technology will be beneficial in drought management. Extra seedling production slightly varying time period will be beneficial in order to cope against drought while seedling transplantation periods. Government support in meeting farmer's demands such as of fertilizer as well as seeds favorable for coping strategies of climate change should be timely forwarded. Alternatives crops and vegetables growing techniques should be disseminated to maintain household food security. Scientific approaches such as regular soil moisture testing, hydrology and meteorological measurements, conducting Farmer's Field Trial of certain rice varieties for varietals testing should be duly promoted by the government bodies and other concerned stakeholders.

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