Research Article

FARMERS' PERCEPTION ON CLIMATE CHANGE AND MAIZE CULTIVATION IN RELATION TO INSECT DIVERSITY ACROSS THE ALTITUDINAL GRADIENT OF NEPAL

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ABSTRACT

Household survey was done with randomly selected 148 respondents from three districts, representing the altitudinal variation focusing to maize growing areas in inner terai (Chitwan), mid (Kaski), and high (Mustang) hills of Nepal to explore the farmers' perception on climatic variabilities and maize production relating to the insect diversity. Data were collected through purposive random sample survey of households using a stratified-multi stage cluster sampling method. Findings revealed that majority of farmers were aware of climate change, particularly about the climatic variability and its impact on maize production, but they posses poor knowledge about appropriate adaptation strategies. The findings also showed that most of the respondent farmers (68.9%) experienced increased temperature whereas about one-third (35.5%) also experienced about erratic rainfall pattern. About three-fifth of the respondent farmers felt about the emergence of insect pests in the last decade, and they relate this fact as the effect of climate change, resulting decreased maize production over the years. Analysis of the recorded temperature revealed an increment of 0.02-0.07°C/ temperature/year with the increment of precipitation of 24.6 mm/year between 1980 and 2018, and these facts matches well to the perception of respondent farmers. Findings also identified the major problems related to the maize production as pest severity, lack of labour, unavailability of improved seed, poor extension service, and frequently occurrence of drought. Likewise, pest attack was also revealed as an important cause of decreased maize production. About two-fifth (44%) respondent farmers considered stem borer as the most prevalent pest in all ecological domains, causing significant damage to maize. Majority of the farmers followed only cultural practices to manage pests whereas their poor knowledge on insect and disease management was the major challenge to increase maize productivity that needs serious consideration for a better policy formulation and planning.

Key words: Temperature, pest emergence, stem borers, management, adaptation strategies

INTRODUCTION

Nepalese farmers are quite vulnerable to the climate change (Gentle & Maraseni, 2012) because most of them rely on weather-dependent rain-fed agricultural system for their subsistence livelihood (Devkota, et al., 2013). After rice, maize (*Zea mays* L.) is the second most important crop of Nepal in terms of both area and production. In Nepal, maize is cultivated in 954,158 ha with the production of 2,555,847 t (MOALD, 2017/18). The factors causing lower yield of maize in Nepal are the use of low-quality seeds, poor crop management practices, and low soil fertility status (Karki et al*.,* 2015). Research findings has shown that rise in summer rainfall and temperature negatively affect yield of maize by 106 kg/ha in Nepal (Joshi et al*.,* 2011).

Insects are considered as poikilothermic animals in which body temperature is variable and dependent on temperature, and are greatly affected by changing temperature (Sable & Rana, 2016). The mean annual temperature is estimated to increase by 0.06^{o}C annually, and is projected to increase by another 1.2^{o}C by 2030; 1.7^{o}C by 2050, and 3.0^{o}C by 2100 in Nepal (MoE, 2010). Increased temperature has resulted in northward migration of some insects. Consequences of increment in temperature could be such that it may affect insect development rate, oviposition, create environment for insect outbreaks, and there may be introduction of invasive species, and insect extinctions (Sable & Rana, 2016). With rise in temperature, the insect-pests are expected to extend their geographic range from tropics and subtropics to temperate regions at higher altitudes along with shifts in cultivation areas of their host plants (Sharma et al*.,* 2010). Major insect pests, such as cereal stem borers (*Chilo, Sesamia* and *Scirpophaga)*, pod borers (*Helicoverpa, Maruca* and *Spodoptera*), aphids, and whiteflies may move to temperate regions, leading to greater damage in cereals, grain legumes, vegetables and fruit crops (Sharma, 2014). Many beetles, butterflies, dragonflies, grasshoppers, and aquatic bugs have moved northward and to higher elevations in the United Kingdom (Hickling et al*.,* 2006). Any increase in temperature is bound to influence the distribution of insects that 1ºC rise in temperature would enable in northern hemisphere or 40 m upward (in altitude) (Pareek et al*.,* 2017). The areas that are not favorable at present due to low temperature may become favorable with rise in temperature. To sum this information, climate change has been affecting the major insects/pests diversity in the recent years and is important factor affecting crop yields in Nepal (Malla, 2008). Therefore, this study was done to understand farmers' perceptions, to those residing across the altitudinal gradients, on the insect distribution, diversity, its effect on crop production, focusing to the maize, by also considering the copping strategies with respect to climatic variabilities so that appropriate strategies to safeguard the crop damage against insect-pest could be minimized and production potential could be increased.

MATERIAL AND METHODS

Study area

The study was conducted on maize dependent smallholders in different ecological belts of central Nepal where maize production is predominately rain-fed. The study site is located 28.39^0 N and 84.12^0 E, with diverse agro-ecology and socio-economic systems, which fairly represent the maize growing areas from inner terai/low land to high hills of Nepal (Figure 1, Table 1). Out of four clusters identified, the 1st is Bhimnagar, Chitwan cluster, lying in the inner terai, in the hot and humid tropical belt below 300 masl. The 2nd includes Puranchaur, Kaski cluster, located in the wet and humid zone (between 900-1000 masl) in the foot hills. The 3rd one is Lumle, Kaski cluster, which is located in the cool, wet temperate zone (1700-1800 masl) in the mid hill. The fourth cluster Lete, Mustang is located in the cold, dry Trans-Himalyan zone (between 2500-2600 masl) of Nepal.

Table 1. Geographical distribution and weather variations of study areas

Location	Region	Latitude	Longitude	Altitude (masl)	Mean annual temperature (^{0}C)	Mean annual precipitation (mm)
Bhimnagar, Chitwan	Inner terai	27.63^0 N	84.31^0 E	176-228	24.3	165.8
Puranchaur, Kaski	Foot hill	28.31^0 N	83.97^0 E	900-1000	20.9	310.7
Lumle, Kaski	Mid hill	28.38^0 N	83.83^0 E	1700-1800	16.1	453.9
Lete, Mustang	High hill	28.60^0 N	83.60^0 E	2500-2600	11.7	120.1

Masl=Meter above sea level, (^{0}C)=Degree centigrade, mm=millimeter, N=North, E=Earth

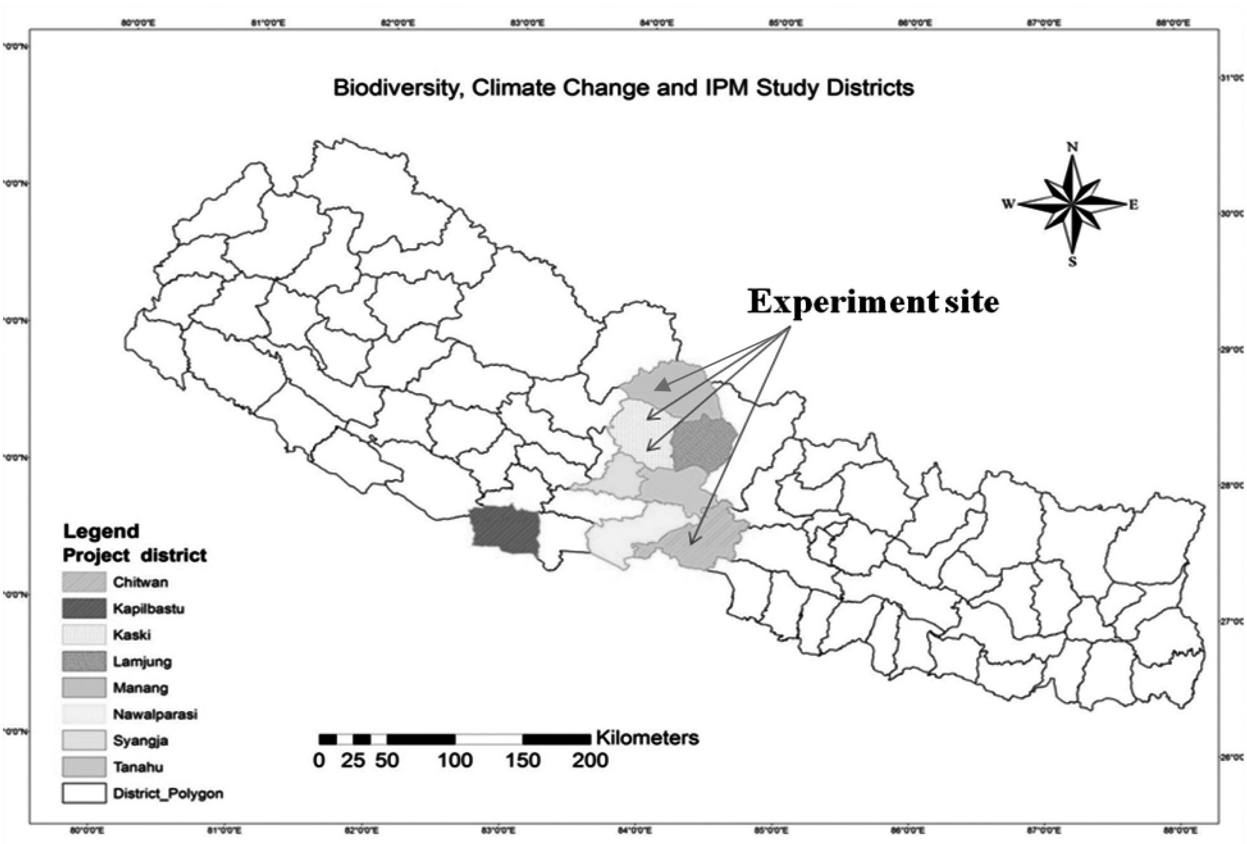

Figure 1. Map of Nepal showing study area

Selection of households

Quantitative data with respect to the effects of climatic variables, factors affecting maize production and productivity, local adaptation practices for maize pest management, and the impact of climate change on productivity of maize crop were collected through purposive random sample survey of households using a stratified-multi stage cluster sampling method. A total of 148 respondent farmers (40 households in Bhimnagar, 39 households in Puranchaur, 38 in Lumle and 31 in Lete) were randomly selected from maize growing areas.

Interview schedule

The problems related to climate change, insect diversity in maize crop and impact in food security were conceptualized after an intensive literature review. Then, primary information was collected from key informants using semi-structured questionnaires. The questions were focused broadly on issues of climate change; perceptions of local people on climate change; change in crop yield; insect diversity; food availability, knowledge on pesticides and effect, and its alternative to ensure food security.

Data analysis

Data were organized in Microsoft Excel spread sheet and analyzed by using SPSS (IBM, 2020, USA). Both Non-parametric (Chi-square (χ^2) test) and inferential (t-test) test were done along with descriptive statistics (means, percentage and frequency).

Climate data

Meteorological data (temperature and rainfall records) were obtained from four weather stations, such as-Rampur, Malepatan, Lumle and Lete Meteorological Stations which are located in the nearby areas of the study sites. The spatial variations of temperature and precipitation data record were analyzed covering the duration of 1980 to 2018 for Rampur, Malepatan and Lumle; and for the duration of 1998 to 2016 for Lete weather stations, respectively (Figures 2, 3).

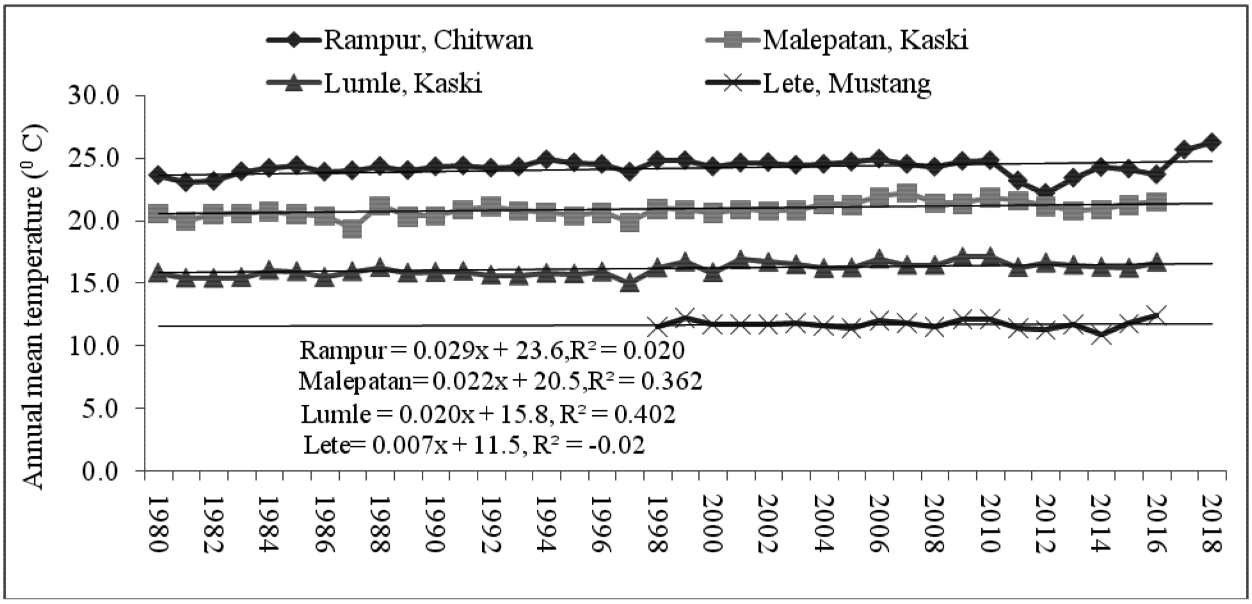

Figure 2. Annual mean temperature (^{0}C) for the last 38 years in the study area

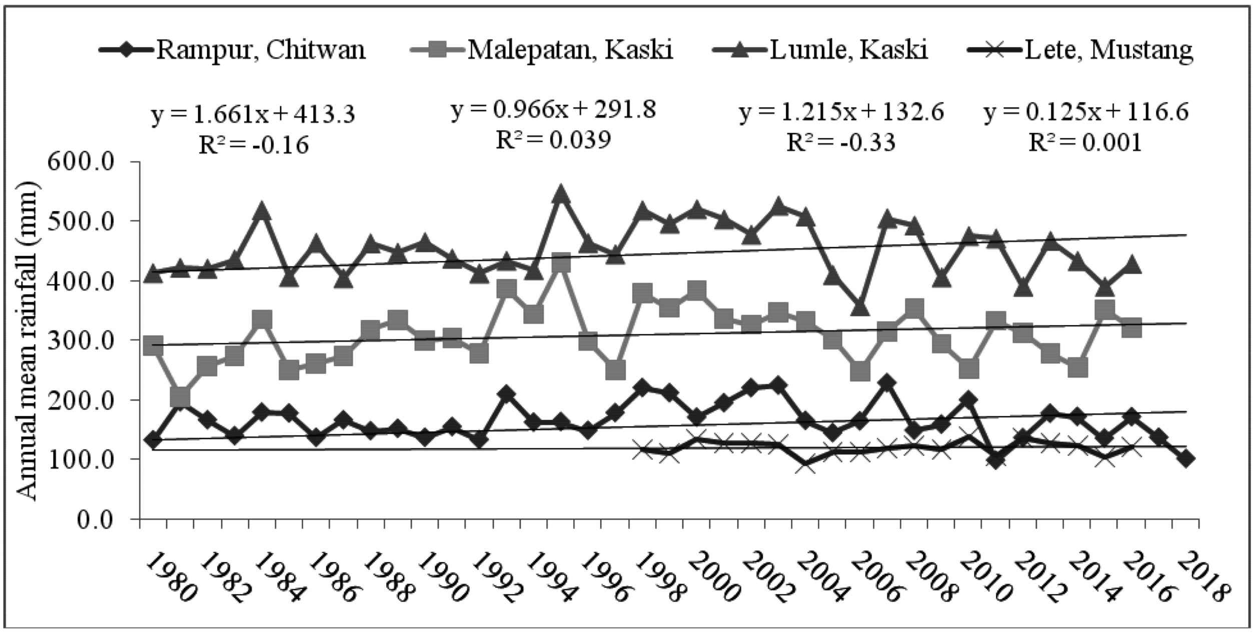

Figure 3. Annual mean rainfall (mm) for the last 38 years in the study area

RESULTS AND DISCUSSION

Demographic and socio-economic characteristics

An overview of household demographic and landholding situation of respondent farmers in the study areas has been presented in Table (2). Out of 148 respondents, over two-third (66.9%) were Bramin/Chetri followed by Janjati (18.9%) and Dalit (14.2%), respectively. Surveyed households had 54.7% male and 45.3% female. Annual household survey (2015/16) reported that 25.9% of the households in the survey area were headed by female members in Nepal. In terms of land holdings, majority of households (38%) cultivated land ranging 0.3-0.5 ha in the study area. About three fourth of the respondents represented the age category of 20-60 years (Table 2). According to CBS (2011), small landholders and marginal farmers pre-dominate Nepalese agriculture with the average holding size of 0.8 ha. Nearly half of all farms have less than 0.5 hectare of land.

Table 2. Household demographic and socio-economic characteristics (n=148) across the study districts

Demographic categories	Bhimnagar, Chitwan (n=40)	Puranchaur, Kaski(n=39)	Lumle, Kaski (n=38)	Lete, Mustang (n=31)	Total (n=148)	Chi-square value
Caste/ethnicity						
Bramin/Chetri	31 (77.5)	37 (94.9)	30 (78.9)	1 (3.2)	99 (66.9)	81.371*** (p=.000 at 6 df)
Janajati	9 (22.5)	0 (0.0)	3 (7.9)	16 (51.6)	28 (18.9)	
Dalit	0 (0.0)	2 (5.1)	5 (13.2)	14 (45.2)	21 (14.2)	
Sex of respondent						
Male	23 (57.5)	19 (48.7)	21 (55.3)	18 (38.1)	81 (54.7)	0.836 (p=0.841 at 3 df
Female	17 (42.5)	20 (51.3)	17 (44.7)	13 (41.9)	67 (45.3)	
Age of respondent						
<20 year	0 (0.0)	0 (0.0)	2 (5.3)	1 (3.2)	3 (2.0)	7.374 (p=0.288 at 6 df
20-60 year	25 (62.5)	19 (48.7)	25 (65.8)	18 (58.1)	87 (58.8)	
> 60 year	15 (37.5)	20 (51.3)	11 (28.9)	12 (38.7)	58 (39.2)	
House hold land holding(Ropani)						
<5	8 (20.0)	9 (23.1)	8 (21.1)	19 (16.3)	44 (29.7)	29.938*** (P=.000 at 9 df)
6-10	15 (37.5)	13 (33.3)	22 (57.9)	6 (19.4)	56 (37.8)	
11-15	13 (32.5)	15 (38.5)	5 (13.2)	3 (9.7)	16 (24.3)	
>15	4 (10.0)	2 (5.1)	3 (7.9)	3 (9.7)	12 (8.1)	
Household head						
Male	33 (82.5)	32 (82.1)	28 (73.7)	24 (77.4)	117 (79.1)	1.210 (p=0.751 at 3 df
Female	7 (17.5)	7 (17.9)	10 (26.3)	7 (22.6)	31 (20.9)	

Note: Figures in parentheses indicate percentage. **Resembles statistical significance at p<0.001; 20 ropani=1ha

Farmer's perception on climate change

The climate of Nepal is mainly characterized by altitude, topography and seasonal atmospheric circulations whereas climatic variability, mainly that related to temperature and precipitation are considered more important part of climate change in view of the common farmers in Nepal. Findings revealed that about four-fifth of the respondents were aware about the concept of climate change whereas similar proportion of the respondents had perceived changes in local climate during the last decade. Similarly, almost all the respondent farmers expressed the impact of climate change in agriculture as well as non agriculture sectors (Figure 4). Farmers have identified climate change indicators in various forms, e.g., an increase in temperature, an increase in precipitation and an increase in fog and cold wave (Tables 3, 4, & 5). Similar trend in response was also reported by Paudel et al., (2020) where an increase in temperature (99.2% of those surveyed), a decrease in precipitation (98.9%), and an increase in climate-induced diseases and pests (96.8%) for agricultural crops was a major finding of the study. Our study finding thus further support the fact that local farmers' perception about climate change is more or less consistent with the observed data obtained from meteorological stations in Nepal.

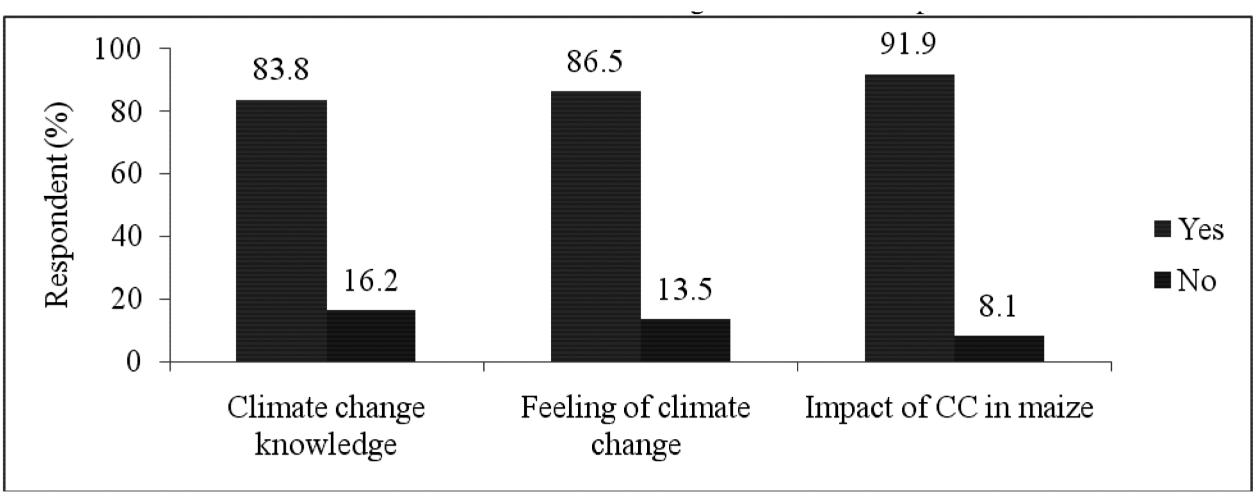

Figure 4. Respondent farmers' perception on climate change and its impact on maize cultivation in study areas

Temperature change

Farmer's perception on change in temperature over the past decade is presented in Table (3). Change in temperature varied significantly (p<0.001). Over two-third of the respondents reported that there was an increase in the mean annual temperature. Moreover, less than 10% of them had no idea about change in temperature. The proportion of farmers who perceived temperature increase was highest in Chitwan district followed by Lumle in Kaski district, respectively. Bedeke et al., (2018) reported a similar observation where most farmers (96.7%) perceived that overall annual mean temperature had increased during the period of 1995-2015. The observed climate records (four stations) of the Department of Hydrology and Meteorology, Nepal covering the period of 1980 and 2018 show that the annual mean temperature significantly increased by 0.02-0.07°C/year (Figure 2). These perceptions are supported by the historical records at Khudi station, which show that the minimum temperature increased 0.07°C per year and the maximum temperature increased 0.02°C per year during the period of 1980 to 2012 (Paudel et al., 2017). Likewise, Pokhrel and Pandey (2011) also reported that average annual temperature has been raised by 0.06°C per year along with the rise in temperature of 0.06°C to 0.12°C/year in most of middle mountain and Himalayan regions, while it was less than 0.03°C/year for Siwalik and Terai region over the period 1971-1994. Similarly, average temperature has increased consistently and continuously, at a rate of 0.025˚C/year from 1970s to 2000 (Devkota, 2014).

Table 3. Respondent farmers' perception on temperature change in the study area

Change trend (annual mean)	Bhimnagar, Chitwan (n=40)	Puranchaur, Kaski (n=39)	Lumle, Kaski (n=38)	Lete, Mustang (n=31)	Total (n=148)	Chi-square value
Decreasing	2 (5.0)	5 (12.6)	1 (2.6)	6 (19.4)	14 (9.5)	23.419** (p=.005 at 9 df)
Increasing	32 (80.0)	24 (61.5)	30 (78.9)	16 (51.6)	102 (68.9)	
Indifferent	4 (10.0)	2 (5.1)	7 (18.4)	3 (9.7)	16 (10.8)	
No idea	2 (5.0)	8 (20.5)	0 (0.0)	6 (19.4)	16 (10.8)	

Note: Figures in parentheses indicate percentage. **Resembles statistical significance at p<0.001 level

Rainfall variability

Our study findings revealed that around three-fourth of the respondents reported seasonal variability in rainfall pattern in the survey area; about two-fifth perceived increasing in rainfall intensity and about similar proportion also reported decreasing in rainfall duration in the last decade (Table 4). Respondent famers noticed that the starting and ending time of monsoon was late, that indicate changing pattern of rainfall. Our findings clearly indicated that intensity and timing of rainfall has been shifted resulting in erratic rainfall. Parvin & Ahsan (2013) also reported that monsoon time was shifting and also opined untimely rainfall events, as monsoon starts late with intensity pattern high in off monsoon season. Similar kind of study was done by Sujakhu et al., (2016) in the Melamchi Valley in central Nepal and reported that 95% of the respondents perceived an increase in temperature and a decrease in precipitation over the last two decades. The observed climate records between 1980 and 2018 show that the annual mean precipitation significantly increased by 24.6 mm/year (Figure 3). Similar results were also reported by Devkota (2014) indicating that mean precipitation in Nepal is increasing annually by 13 mm, while the number of rainy days is decreasing by 0.8 days/year. Analysis of rainfall data from 1971 to 2005 shows change in annual and seasonal rainfall pattern with overall increase in annual average rainfall by 2.08 mm (Baidya, et al., 2007).

Table 4. Respondent farmers' perception on rainfall pattern in the study area

Change trend	Bhimnagar, Chitwan (n=40)	Puranchaur, Kaski (n=39)	Lumle, Kaski (n=38)	Lete, Mustang (n=31)	Total (n=148)	Chi-square value
Decreasing	25 (62.5)	9 (23.1)	5 (13.2)	13 (41.9)	52 (35.5)	59.575*** (p=.000 at 9 df)
Increasing	10 (25.0)	13 (33.3)	26 (68.4)	8 (25.8)	57 (38.5)	
Indifference	4 (10.0)	1 (2.6)	7 (18.4)	4 (12.9)	16 (10.8)	
No ideas	1 (2.5)	16 (41.0)	0 (0.0)	6 (19.4)	23 (15.5)	

Note: Figures in parentheses indicate percentage. **Resembles statistical significance at $p<0.001$ level

Change in fog and cold wave

Our study findings revealed that about two-fifth of the respondents noticed increasing trend of fog and cold wave over the last decade whereas about one-fifth of them felt about decreasing trend of fog and cold wave ($p<0.001$; Table 5). Farmer's perception on increased period of cold waves over the last 14 years is supported by recorded climate data which show an increasing trend in the number of days of cold waves from 1992 to 2004 (Manandhar et al., 2011).

Table 5. Respondent farmers' perception on fog and cold wave in study area

Change trend	Bhimnagar, Chitwan (n=40)	Puranchaur, Kaski(n=39)	Lumle, Kaski (n=38)	Lete, Mustang (n=31)	Total (n=148)	Chi-square value
Increasing	21 (52.5)	23 (59.0)	9 (23.7)	8 (25.8)	61 (41.2)	26.544** (p=0.002 at 9 df)
Decreasing	3 (7.5)	6 (15.4)	9 (23.7)	7 (22.6)	25 (16.9)	
Indifference	9 (22.5)	6 (15.4)	19 (50.0)	10 (32.3)	44 (29.7)	
No ideas	7 (7.5)	4 (10.3)	1 (2.6)	6 (19.4)	18 (12.2)	

Note: Figures in parentheses indicate percentage. **Resembles statistical significance at $p<0.001$level

Other Indicators of climate change

Besides weather variability such as temperature, rainfall, fog and cold wave, there were increased frequency and timing of snowfall in Lete of Mustang district. Most of the respondents interviewed in Lete reported about decrease in the volume and a change in the timing of snowfall. Decreasing snowfall has been experienced along with increasing winter rain, and less snow cover has been noticed in the Dhaulagiri and Annapurna ranges (Manandhar et al., 2011). The researcher was able to observe the extent and effects of drought in the region (including wildfires during the field research), as well as the unusual sight of no snow on the mountains (e.g., Mt. Nilgiri) and de-glaciated areas in the Dhaulagiri Icefall (Becken et al., 2013). People had perceived rise in temperature, rapid melting of snow, increase in rainfall amount in lower belt, decrease in snowfall in higher belt and unfavorable weather change phenomena (K.C., 2017). Respondents also felt that there were few or no mosquitoes in the past in the site, but the increasing temperature created favorable condition for mosquitoes and many other insects and diseases now-a-day. In the hills, there has been change in intensity and timing of rainfall along with high incidence of pests having adverse effect of agricultural production (Parajuli & Upadhya, 2016).

Climate change effects on maize production

It is important to note that more than 60% of population depends on subsistence agriculture (CBS, 2013), and heavy dependence on agriculture makes Nepal's economy very sensitive to climate variability. Our study revealed the fact that about three-fifth of them have experienced biotic stress, especially due to insect, disease and weeds in maize cultivation in the last decade, which caused low maize production (Table 6). Similar proportion of the respondents has also experienced increase in disease and pests in all ecological belts, mainly due to climate change. This finding is in conformity with the work of Paudel et al., (2019) that climate-induced diseases and pests were experienced severe in terai and hill regions than in the mountain region.

Drought is second abiotic constraint affecting maize production in the study area where about one-tenth of the respondents expressed increasing the days of drought period in the study sites. Climate instability has resulted in variation of the intra-and inter-annual rainfall, and prevailing drought a recurrent problem. Drought events were commonly noted by about one-fourth of the respondents in the high hill regions (Table 6). Unusually severe drought influences the damage by insect species, such as spotted stem borer, *Chilo partellus* in sorghum (Sharma et al., 2005).

Table 6. Respondent farmers perception on effect of climate change on maize cultivation

Indicators	Bhimnagar, Chitwan (n=40)	Puranchaur, Kaski (n=39)	Lumle, Kaski (n=38)	Lete, Mustang (n=31)	Overall (n=148)	Chi-square value
Increase insect, disease, weeds	27 (67.5)	23(59.0)	25(65.8)	12(38.7)	87(58.8)	
Decrease crop production	3(7.5)	6(15.4)	4(10.5)	7(22.6)	20 (13.3)	
Increase drought	6(15.0)	3(7.7)	1(2.6)	8(25.8)	18(12.2)	35.784** (p=0.002 at 15 df)
Increase cost of production	3(7.5)	0(0.0)	1(2.6)	0(0.0)	4(2.7)	
All of the above	0(0.0)	1(2.6)	5(13.2)	0(0.0)	6(4.1)	
No idea	1(0.0)	6(15.4)	2(5.3)	4(12.9)	13(8.8)	

Note: Figures in parentheses indicate percentage. **Resembles statistical significance at p<0.001level

Maize production issues

In this study, prioritization of the problems was based on severity and frequency of occurrence. Accordingly, the most important problem reported by the respondents across the sites were: insects, followed by weed, and combined of disease, insect and weeds, respectively (Table 7). In addition, lack of seed, shortage of labour and market are also important problems. Lack of market was specifically reported only in Bhimnagar cluster. Sapkota et al., (2017) reported that limited amount of improved seed is available in Nepal and it is not sufficient to meet the increasing demand of the improved maize seeds.

Table 7. Respondents' response on constraints of maize production in the study area

Constraint	Locations				Total (n=148)	Chi-square value
	Bhimnagar, Chitwan (n=40)	Puranchaur, Kaski (n=39)	Lumle, Kaski (n=38)	Lete, Mustang (n=31)		
Seed	0 (0.0)	3 (7.7)	9 (23.7)	5 (16.1)	17 (11.5)	
Diseases	3 (7.5)	3 (7.7)	0 (0.0)	2 (6.5)	8 (5.4)	
Insects	15 (37.5)	9 (23.1)	3 (7.9)	14 (45.2)	41 (27.7)	
Weeds	6 (15.0)	13 (33.3)	5 (13.2)	7 (22.6)	31 (20.9)	53.12*** (p=.000 at 18df)
Market	4 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (2.7)	
Diseases+ insects + weeds	9 (22.5)	6 (15.5)	12 (31.6)	3 (9.7)	30 (20.3)	
Labors	3 (7.5)	5 (12.8)	9 (23.7)	0 (0.0)	17 (11.5)	

Note: Figures in parentheses indicate percentage. **Resembles statistical significance at p<0.001 level

Farmer's perception on insect diversity

Emergence of insects

Pest whose status has been changing from minor to major or secondary to primary is termed as an emerging pest. The emergence of new insects or increasing number of existing insect pests in maize was noticed by about three fourth of the respondents (Figure 5). Majority of the respondents in Bhimnagar, Puranchaur, Lumle and Lete areas noticed increased numbers of existing insects and the appearance of new insects in their surroundings (Figure 5). Common insects reported include: stem borers, cutworm, armyworm, white grubs, and aphid on maize crop (Figure 6). Majority of the respondents indicated that stem borer was the most damaging insect pest on maize in all surveyed area. They believed that this was due to the warming trend at all altitudinal level in Nepal. Similar result was reported by Paudyal et al., (2001) in which stem borers, *Chilo partellus* (Swinhoe), white grubs (*Phyllophaga* spp. and *Cyclocephala* spp.), army worms (*Spodoptera* spp., *Mythimna* spp.) and cutworms (*Agrotis* spp. and others) were major insect pest in all agro-ecologies, except the eastern mid hills.

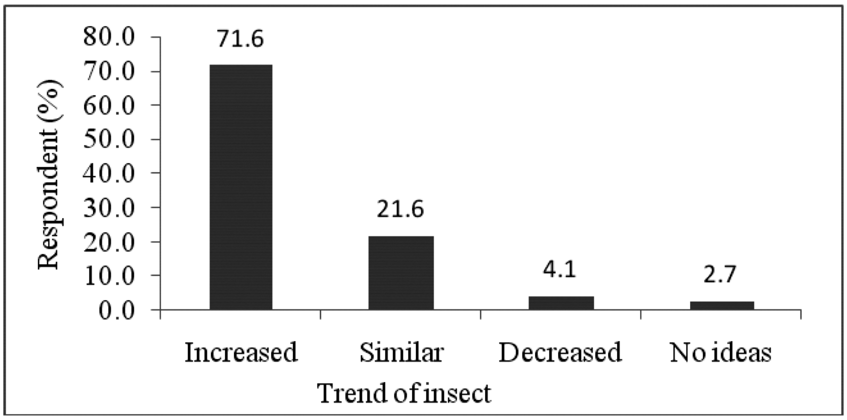

Figure 5. Insect pests' situation in maize

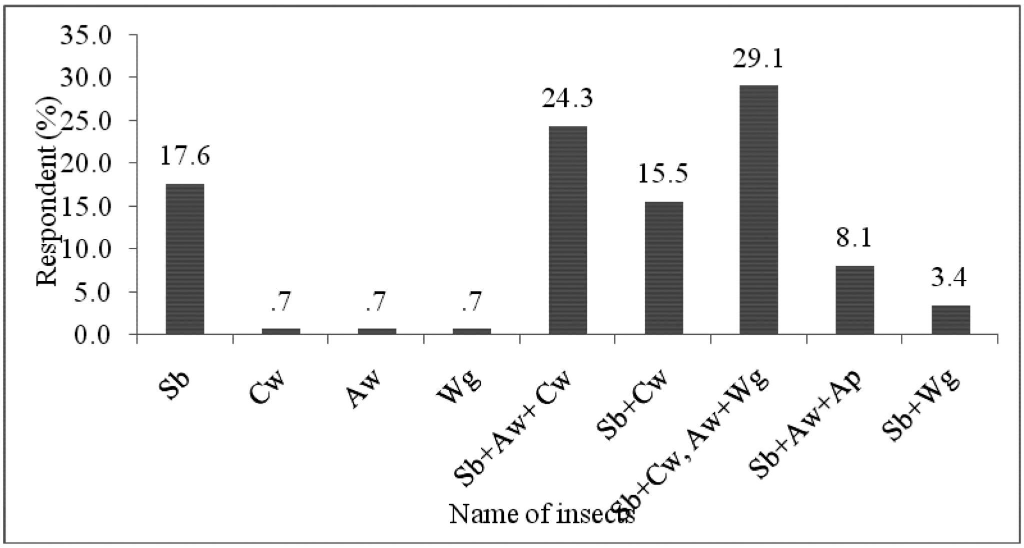

Figure 6. Major insects associated with maize crop in study area

Note: Sb=Stem borer; Cw=Cut worm; Aw=Army worm; Wg=White grubs; Ap=Aphids

Stem borers can be particularly problematic in spring and summer plantings when temperature and insect reproduction are high. Insects in general seem to be less problematic in high hills than in other agro-ecologies. The findings clearly indicated that the intensity of insects was higher with lower altitude and lower intensity with respect to increased altitudinal gradients. Paudel et al., (2019) also reported that climate-induced diseases and pests were experienced severe in terai and hill regions than in the mountain region. Famers of Lete area reported the new insect pests such as stem borer and cutworm in maize fields for past few years.

Major insect pests

Stem borer was the most prevalent and the worst pest in all altitudinal gradients as reported by significant proportion of respondents followed by cutworms, and armyworm (Table 8). These results indicate that the stem borers pose a serious threat to all maize growing area. Several researchers have reported maize stem borer *Chilo partellus* (Swinhoe) as major threat to maize production throughout the country (Bhandari et al., 2018). In addition, armyworm, grass hopper, leaf folder, white grub, cutworm, termite and grey weevil cause extensive localized damage to spring sown maize in foothill areas of Nepal (Thakur et al*.,* 2013). Several insects, such as *Helicoverpa armigera* (Hubner)*, Mythimna separata* (Walker) and *Spodoptera litura* (F.) are migratory and exploit opportunities by moving rapidly into new areas as a result of climate change (Sharma, 2010).

Table 8. Respondent famers' responses on major insect pest associated with maize in survey areas

Major insects	**Locations**				**Total (n=148)**	**Chi-square value**
	Bhimnagar, Chitwan (n=40)	**Puranchaur, Kaski (n=39)**	**Lumle, Kaski (n=38)**	**Lete, Mustang (n=31)**		
Stemborers	19 (47.5)	14(35.9)	21(58.4)	11(35.5)	65(43.9)	
Armyworms	9(22.5)	10(25.6)	3(7.9)	1(3.2)	23(15.5)	43.236*** (p=.001 at 18df)
Cutworms	4(10.0)	10(25.6)	4 (10.5)	8(25.8)	26(17.6)	
Whitegrubs	0(0.0)	2(5.1)	5(13.2)	7(22.6)	12(9.5)	
Aphids	4(10.0)	2(5.1)	3(7.9)	0(0.0)	9(6.1)	
Helicoverpa	4(10.0)	1(2.6)	2(5.3)	1(3.2)	8(5.4)	
Red ants	0(0.0)	0(0.0)	0(0.0)	3(9.7)	3(2.0)	

Figures in parentheses indicate percentage. **Resembles statistical significance at 1% level

Yield loss due to stem borers

The severity of losses caused by the stem borers varied based on its management practices adopted by the famers. The yield loss was mainly experienced by the two fifth of respondents in Bhimnagar whereas about one fifth of respondents from Puranchaur and Lumle also had significant yield loss due to stem borer (Table 9). Maize yield is reduced in Nepal as about 20 to 80% by the stem borers (Achhami et al., 2015).

Table 9. Mean comparison of annual stem borer damage in maize with altitudinal expansion

Variable	**Overall (n=148)**	**Bhimnagar, Chitwan (n=40)**	**Puranchaur, Kaski (n=39)**	**Lumle, Kaski (n=38)**	**Lete, Mustang (n=31)**	**t-value**
Stem borer damage (%)	25.21 (18.69)	42.75 (21.15)	20.43 (12.02)	21.05 (14.35)	13.70 (9.79)	25.76***(p=.001)

*** Highly significant (p<0.001)

Insect pest management

In this study, we found that about one-third of the respondent farmers did nothing for insect pest management, while about one third of them relied only on chemical pesticides to control pests. High dependency on chemical pesticides of respondent farmers (80%) on maize production in Bhimnagar area of Nepal is attributed to hybrid maize cultivation targeting to supply for feed industries (Table 10). Similar result was also reported by Ghimire & Khadka, (2005) that 90% farmers used synthetic chemical pesticides and remaining 10% did nothing to control the pest. Likewise, around one-fifth of the respondents followed a cultural management practice whereas a few farmers (5%) relied on mechanical and physical practices.

Table 10. Existing pest management practices among maize growers in the study area

Management tools	Locations				Total (n=148)	Chi-square value
	Bhimnagar, Chitwan (n=40)	Puranchaur, Kaski (n=39)	Lumle, Kaski (n=38)	Lete, Mustang (n=31)		
Cultural method	3 (7.5)	8(20.5)	10(26.3)	5(16.1)	26(17.6)	98.702*** (p=.000 at 15df)
Botanical method	3(7.5)	8(20.5)	8(21.1)	2(6.5)	21(14.2)	
Mechanical+Physical method	0(0.0)	2(5.1)	0(0.0)	5(16.1)	7(4.7)	
Chemical method	32(80.0)	9(23.1)	1(2.6)	1 (3.2)	43 (29.1)	
Biological method	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Nothing done	2(5.0)	10(25.1)	19(50.0)	18 (58.1)	49 (33.1)	
Local and chemical method	0(0.0)	2(5.1)	0(0.0)	0(0.0)	2(1.4)	

Note: Figures in parentheses indicate percentage. **resembles statistical significance at p<0.001 level

Adaptation to climate change

Adaption to climate change relating to maize insect pest management was highly significant (p<0.001). In deed about one third of the smallholder farmers had implemented a variety of adaptation practices whereas similar proportion relied only on chemical pesticides to control pests. Similar result was also reported by Ghimire & Khadka, (2005) that 90% farmers used synthetic chemical pesticides and remaining 10% did nothing to control the pest. The major coping strategies followed by the farmers appeared to be changing the crop varieties and shifting the crop plantation season (Dahal et al., 2018). Other common adaptation practices included applying pesticides and use of intercropping practice (Table 11). The most common method that was frequently used to control insect pests and perceived as effective by most of the farmers was the use of synthetic pesticide (Laizer et al., 2019) whereas nearly half of the respondents stated that they were using improved varieties of crops and improved production technology.

Table 11. Copping strategies followed by farmers to overcome the maize pests in the study area

Adaptation strategies	Locations				Total (n=148)	Chi-square value
	Bhimnagar, Chitwan (n=40)	Puranchaur, Kaski (n=39)	Lumle, Kaski (n=38)	Lete, Mustang (n=31)		
Change in varieties	7 (17.5)	14 (35.9)	19 (50.0)	0 (0.0)	40 (27.0)	139.189*** (p=.000 at 21df)
Change in planting time	1 (2.5)	1 (2.6)	9 (23.7)	2 (6.5)	13 (8.8)	
Change in crops	1 (2.5)	0 (0.0)	3 (7.9)	9 (29.0)	13 (8.8)	
Change in technology	1 (2.5)	0 (0.0)	0 (0.0)	1 (3.1)	2 (1.4)	
Use of pesticides	22 (55.0)	7 (17.9)	0 (0.0)	0 (0.0)	29 (19.6)	
Use of intercropping	0 (0.0)	10 (25.6)	6 (15.8)	9 (29.0)	25 (16.9)	
Nothing done	1 (2.5)	7 (17.9)	1 (2.6)	10 (32.3)	19 (12.8)	
Change in varieties and technology	7 (17.5)	0 (0.0)	0 (0.0)	0 (0.0)	7 (4.7)	

Note: Figures in parentheses indicate percentage. **denotes statistical significance at p<0.001 level

CONCLUSION

This study was done to assess farmer's perception about climate change; specifically about climatic variability focusing to the maize production across the altitudinal gradients that are more affected by climate induced insect pests. We found that temperature has been increasing and precipitation shows erratic pattern in all the study sites for last three decades, or more. The findings clearly indicated that the intensity of insects was higher with lower altitude and lower intensity with respect to increased altitudinal gradients. It was also revealed that stem borers pose a serious threat to maize growing area including high hill region of Nepal. In conclusion, effective research and extension system with advocacy program on climate resilient farming practices would be better to implement, especially to the small holder maize growers in different agro-ecological domains to safeguard their production potentials aiming to increase in productivity.

ACKNOWLEDGEMENTS

This work was funded in whole by the United States Agency for International Development (USAID) Bureau of Food Security under the Cooperative Agreement No. AID-OAA-L-15-00001 as part of Feed the Future Innovation Lab for Integrated Pest Management through a grant awarded for the "Participatory Biodiversity and Climate Change Assessment for Integrated Pest Management in the Chitwan Annapurna Landscape, Nepal" project executed by Directorate of Research and Extension (DOREX), Agriculture and Forestry University (AFU), Rampur, Nepal. The authors are thankful to Dr. Rangaswamy Muniappan (Virginia Tech, USA), NMRP (NARC) and Central Department of Botany, Tribhuvan University involved in the research project for their support, encouragement and advice.

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