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ORIGINAL PAPER

An assessment by subsistence farmers of the risks to food security attributable to climate change in Makwanpur, Nepal

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Abstract The potential impacts of climate change on the food security of subsistence farmers is a serious concern. This article explores the food security situations of two categories of subsistence farm households, vegetable- and cereal-based farming systems, in the Makwanpur district of Nepal in the context of climate change. Local climate data for the past 30 years were analyzed. Interviews with local farmers and key informants, and focus group discussions were carried out to collect the primary data. Empirical data showed that changes in climate variables for the study period were in line with farmers' perceptions and that farming communities were negatively impacted. Perceived impacts were erratic rainfall, increased frequency of floods and droughts, soil degradation and insect pests, weeds and diseases. Farmers have modified traditional cropping patterns and calendar, changed crop varieties and increased fertilizer and pesticide applications in order to maintain crop yields. They have also sought off-farm employment. However, agricultural productivity in the area is declining and only one third of all households in the area were food secure. Household food insecurity was at mild to moderate levels, but vegetable-based households were more secure than cereal-based ones. At the household level, locally successful adaptive measures, such as rainwater harvesting, mulching, planting date adjustments, off-farm opportunities, including infrastructure and extension support, could increase production and contribute to reversing the impact of increased risk attributed to climate change.

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Keywords Climate Change · Subsistence Farming · Food security · Perception · Adaptation

Introduction

Agriculture is an important sector in Nepal as it contributes 39 % of the country's GDP (MoAC 2010) and two thirds of the country's economically active population depends on it for employment and for their livelihoods (WFP and NDRI 2010). Nepal's agriculture is characterized by traditional low input farming practices and relies mainly on natural rainfall as only 40 % of the agricultural land is irrigated (Gentle and Maraseni 2012; MoAC et al. 2009) making this sector highly climate sensitive (World Bank 2002; Easterling et al. 2007; IPCC, 2007), and hence raising food security concerns. Increasing prevalence of natural disasters within Nepal, such as droughts, flooding, landslides and hailstorms with large stones correlates with variation in climate (MoAC et al. 2009) and has caused adverse impacts on agriculture, such as reduced soil fertility and agricultural production (Regmi and Adhikari 2007; Malla 2008; Bhandari 2008). Crop failures have been experienced in many places, increasing the risk of food insecurity for the majority of the people (Regmi et al. 2008; Jones and Boyd 2011; Gentle and Maraseni 2012). The country's annual food deficit and regular imports of food from neighboring countries are associated with these adverse impacts on agricultural production. Severity of the impacts of climate extremes depends strongly on the level of exposure and vulnerability (IPCC 2012) and generally affects the poorer nations and communities more harshly (Barett, 2002; NRC, 2010) due to several factors, such as socioeconomic, demographic, and policy, limiting farmers' capacity to adapt to climate change (Morton, 2007).

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (FAO, 2003). Four pillars that build up food security are: i) food availability, i.e. sufficient availability of food both in quantity and quality in a consistent manner, ii) food accessibility, i.e. allocation, affordability and preference of food to achieve a nourishing diet, iii) food utilization, i.e. diversity of food consumed per day, and iv) food system stability, i.e. temporal availability of, and access to, food (FAO, 2008).

The underlying causes of food insecurity in Nepal are complex and require a thorough assessment of interventions (WFP and NDRI, 2010). Studies indicate that the impacts of climate change are significant depending on assumed socioeconomic development (Schmidhuber and Tubiello, 2007), especially on those subsistence farm households that are highly dependent on agriculture and have lower incomes (Morton, 2007). Most literature on the impact of climate change on agriculture are focused on quantitative projections of future impacts at geographical scales (Lasco and Boer, 2006). There has not been adequate discussion that engages with both the impact of climate change on agriculture and the specificities of smallholder and subsistence systems (Morton, 2007), although some discussion exists on the effects of climate change on rural areas of developing countries. Improved understanding of the influence of climate change on agricultural production and food security is needed (Misselhorn, 2005) by appreciating farmers' perceptions and adaptation to climate change in the local social, economic and institutional context of food insecurity (Bryant et al. 2000; Smit and Skinner 2002; Codjoe and Owusu 2011; Li et al. 2010), allowing them to cope and eventually develop appropriate farming practices (Rowhani et al. 2011; Vermeulen et al. 2012). It is in this context that a perception-based study was carried out in the Makwanpur district, a predominantly agricultural region of Nepal, to explore the food security situation of farm households, specifically focusing on the impact of climate variation on agricultural productivity and food security, and existing adaptation measures.

Research method

Study area

The Makwanpur district of Nepal was selected as the study area due to the high dependence of the local population on agriculture and the frequent occurrence of floods, landslides and prolonged winter droughts. The district lies in central Nepal between 27°10′ and 27°40′ North latitude and 84°41′ to 85°31′ East longitude (Fig. 1) covering an area of 2426 km^2

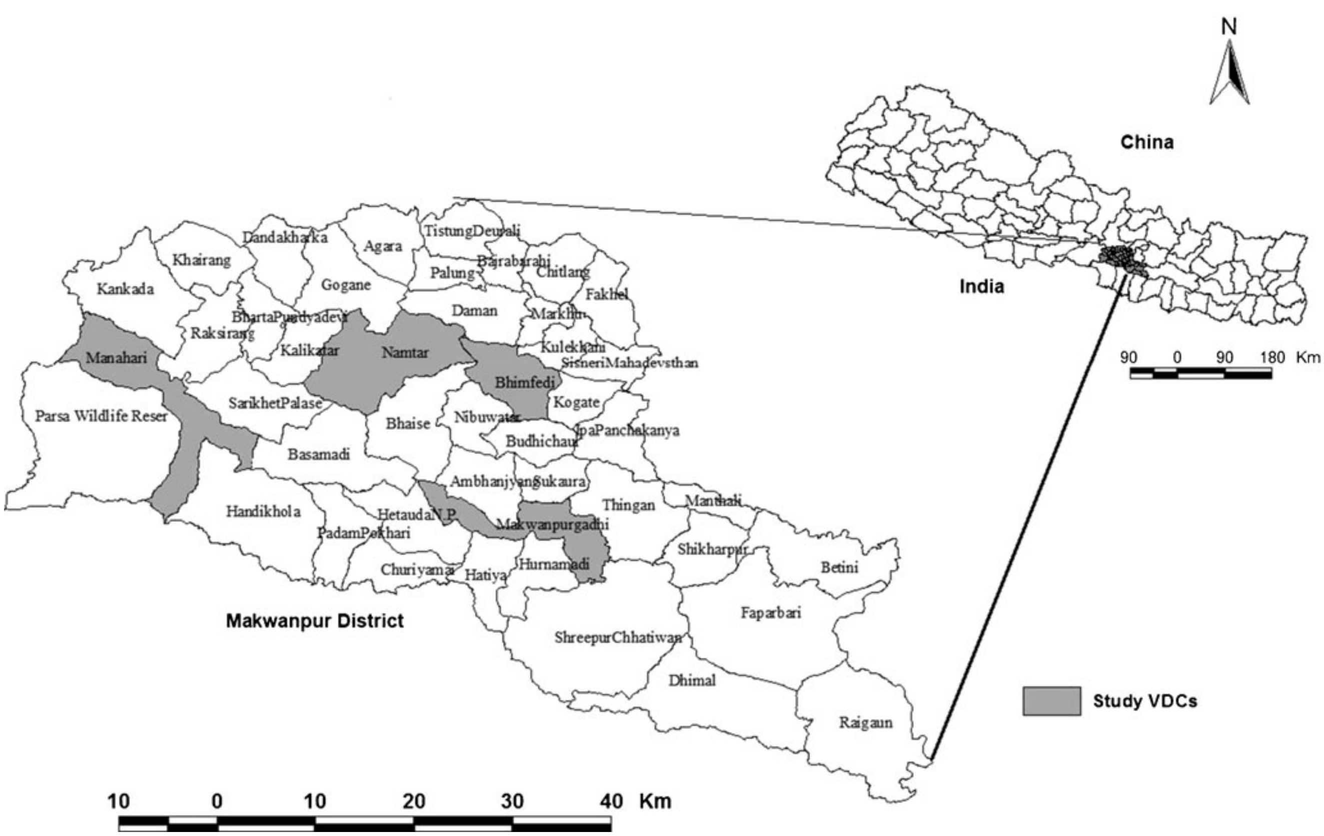

Fig. 1 Location map of study area

with elevations between 166 and 2584 m above sea level (CBS, 2005). More than half of the district has a slope inclination greater than 30^0 making the area vulnerable to landslides and soil erosion along the major rivers, namely Rapti and Bagmati, and their tributaries. The climate ranges from tropical towards the south to temperate towards the north. The highest temperature (38^0 C) is experienced from April to May, and the average annual rainfall varies from 1838 to 3315 mm (DHM, 2005).

The majority of the population in the study area rely on agriculture for their livelihoods. Agriculture is rainfed and characterized by small land holdings, manual labor and traditional farming practices. The major cultivated food crops are rice in winter and autumn and wheat and maize in summer and winter. Potato, cauliflower, cabbage, tomatoes, carrot and cucumber are the main vegetables produced at the relatively higher altitudes of the study area.

Data collection and analysis

Data collection was accomplished by adopting two-stage purposive random sampling. First, a total of four Village Development Committees (VDCs), the lowest administrative unit of Makwanpur district, were selected in consultation with the District offices of Agriculture, Dairy Corporation, and World Food Program. Among the four VDCs, Makawanpurgadhi and Namtar have a vegetable-based farming system and are hilly regions, where landslides are prevalent. The other two VDCs, namely Manahari and Bhimphedi, are in the plain area, which is affected by floods and has a cereal-based farming system. There were 7904 households in the four VDCs and a total of 266 households (HH) was calculated as sample size for conducting a household survey using the equation given by Yamane (1967) at 0.1 error limit. Three hundred HHs, i.e. 75 from each VDC, were randomly selected for interview including 30 for pretesting the questionnaire. The questionnaire was adjusted after pretesting before its use in face-to-face interviews of sampled households during August-October 2010. Information was collected on the socio-economics of households, trends in climate change, farmers' perception of climate change, impact of climate change on agriculture, food security and adaptation practices.

A wide variety of survey instruments exist for collecting information on the various dimensions of food security, with tremendous variation across surveys in content, quality, and quantity of information. Examples of these surveys are Household Budget, Income and Expenditure, Living Standards Measurement, Multi-Purpose and Integrated Household, Demographic and Health, Comprehensive Food Security and Vulnerability Analysis, 24-Hour Nutrition. Similarly, there are also several indicators that are currently being used for food security analysis and monitoring with differing methods of data collection, aggregation, and analysis reflecting the lack of a consensual approach. Some of the widely used indicators of food security, such as Undernourishment and Food Consumption as used by the Food and Agriculture Organization (FAO), Dietary Diversity and Food Insecurity Scale by Food and Nutrition Technical Assistance (FANTA) project, Food Consumption Score by the World Food Program (WFP), Coping Strategy Index by CARE/WFP are in practice (see Carletto et al. 2013 for detail). We used the Household Food Insecurity Access Scale (HFIAS) as suggested by Coates et al. (2007) to describe food vulnerability. This method assumes that the experience of food insecurity (access) can be quantified by capturing predictable reactions and responses generated through the survey.

In addition to primary data collection, interviews of ten key informants were also conducted to collect food security information. Key informants interviewed included officials from government and non-government organizations, local leaders and community elders. Eight Focus group discussions (FGD), two in each VDC, were carried out with farmer groups formed by the District Agriculture Development Office (DADO). The purpose of key informant interviews was to collect the information of common interest to the community, while FGD provided an opportunity to understand the status, needs and aspirations of two specific groups, idenfied as vegetable and cereal growers. Although no separate analysis was done using information from key informant interviews and FGDs, this information was used to triangulate the information collected from the household survey for better understanding of the issues. Other needed secondary data were also collected from various relevant sources, for instance temperature and rainfall data for the 30 years period 1980–2009 were collected from the Department of Hydrology and Meteorology (DHM) of Nepal and were analyzed using RCLIMDEX ver. 2.1 software. For trend analysis of temperature and rainfall data, the data was first smoothed using moving averages to address the high fluctuations in the recorded temperature and rainfall data. Six indicators, as recommended by the World Meteorological Organization and Expert Team on Climate Change Detection, Monitoring and Indices, were used in this study. Threshold values were identified from daily temperature records and their mean, maximum and minimum values, as well as rainfall data, collected over the 30 year period (1980–2009), to identify aberrant values.

The use of Likert-type scales is a common research method for eliciting opinions and attitudes in social and business sciences since its original inception in 1932 (Ryan and Garland 1999). Opinions on climate change impact on food availability measured as perceived impact (no, low, medium or high) by HHs were combined to summarize the data by using a weighted average index (WAI) as shown in the following equation.

$$FAI = \frac{4fH = 3fM + 2fL + fNC}{n}$$

where, *FAI* = Climate change impact on food availability index, *fH* = Number of HHs with responses to high group; *fM* = Number of HHs with responses to medium group; *fL* = Number of HHs with responses to low group; *fNC* = Number of HHs with responses to no change group, *n* = total response

Results and discussion

Household characteristics

Household characteristics of the two distinct farming systems, i.e. vegetable-based farming system (VFS) and cereal-based farming system (CFS) are presented in Table 1. The average HH size in VFS was higher with five family members compared to the four of CFS. Similarly, education levels, as determined by literacy, of both males and females were slightly higher in VFS households than CFS households. CFS households have relatively larger land holdings as can be seen by the fact that 53 % have more than 0.5 ha compared to 49 % in VFS households. Three-quarters of VFS households earned more than 100 USD annually by selling their farm products as opposed to none in CFS households. However, cereals are mostly used for home consumption and hence there is less opportunity for selling them. Sixty-one percent of VFS households sought off-farm employment compared to 93 % of CFS households because for CFS households cropping is seasonal and farmers have time for off-farm employment whereas VFS households grow vegetables all the year round.

Table 1 Household characteristics

Household characteristics	VFS	CFS
Average HH size (members)	5	4
Education (% population)		
Literacy rate in Male	80	76
Literacy rate in Female	67	60
Land holdings (% HH)		
Less than 0.5 ha	51	47
0.5 to 1.5 ha	49	53
Source of water for farming (% HH)		
Natural rain	28	47
Irrigation	72	53
Farm mechanization (% HH)		
Hired tractors	0	47
Motor pumps	11	35

HH = Household; VFS = Vegetable-based farming system; CFS = Cereals-based farming system

Vegetable-based households do not use tractors but instead use human and animal labor owing to the hilly landscape as opposed to cereal-based HH whose farmlands are located in the plain on a relatively flat area and do hire tractors. Irrigation is important for VFS HH who have a more organized irrigation system than CFS HH as can be seen by the higher proportion (72 %) of VFS households using irrigation against 53 % of CFS HH.

Trends in temperature and precipitation

The average annual maximum and minimum temperatures in Fig. 2 refer to the monthly means and the mean diurnal temperature range (DTR) refers to the differences between these means. These values showed an increasing trend for the period 1980 to 2009 (Fig. 2). The trend line shows that the mean annual diurnal temperature range has increased in the last 30 years. Average maximum temperature for the last 30 years was 38.41 °C. The year, 2008, was the hottest with a maximum temperature of 39.55 °C, an increase of 0.046 °C per year during the last 30 years compared to the national average of 0.06 °C, as reported by Shrestha et al. (1999). The minimum temperature increased by 0.009 °C per year over the same period. DTR was greater during 2000–2010 with an average value of 14.67 °C compared with the 12.41 °C of the previous decade, despite a dip in the early half of the 2000s (Fig. 2). Similar results were obtained for the hilly region of the country as reported by Baidya et al. (2008).

To examine the trend of rainfall, three indices, namely number of Consecutive Dry Days (rainfall <1 mm; CDD), number of Consecutive Wet Days (rainfall >1 mm; CWD) and annual precipitation (annual total of wet days with rainfall >1 mm), were considered. CDD increased significantly for the first 20 years but became more variable subsequently. CWD decreased significantly from about 20 in the first 7 years of the study period to about 15 in the last 7 years. The annual average rainfall was 2436 mm with above average rainfall observed between the years 1996 and 2004 (Fig. 2).

During the field survey, farmers were asked about their perception of changes in temperature over a period of 10 years (2001–2011). According to the respondents, the summer days were hotter and the number of winter days had become fewer. The numbers of hot days had increased according to 83 % and 98 % of VFS and CFS households, respectively. Farmer group discussions and key informant interviews also concluded that the number of hot days had increased. Hot days were hotter in the months of April, May and June while cold waves were colder in the months of December and January compared to their intensity in the past. Decreases in the numbers of cold

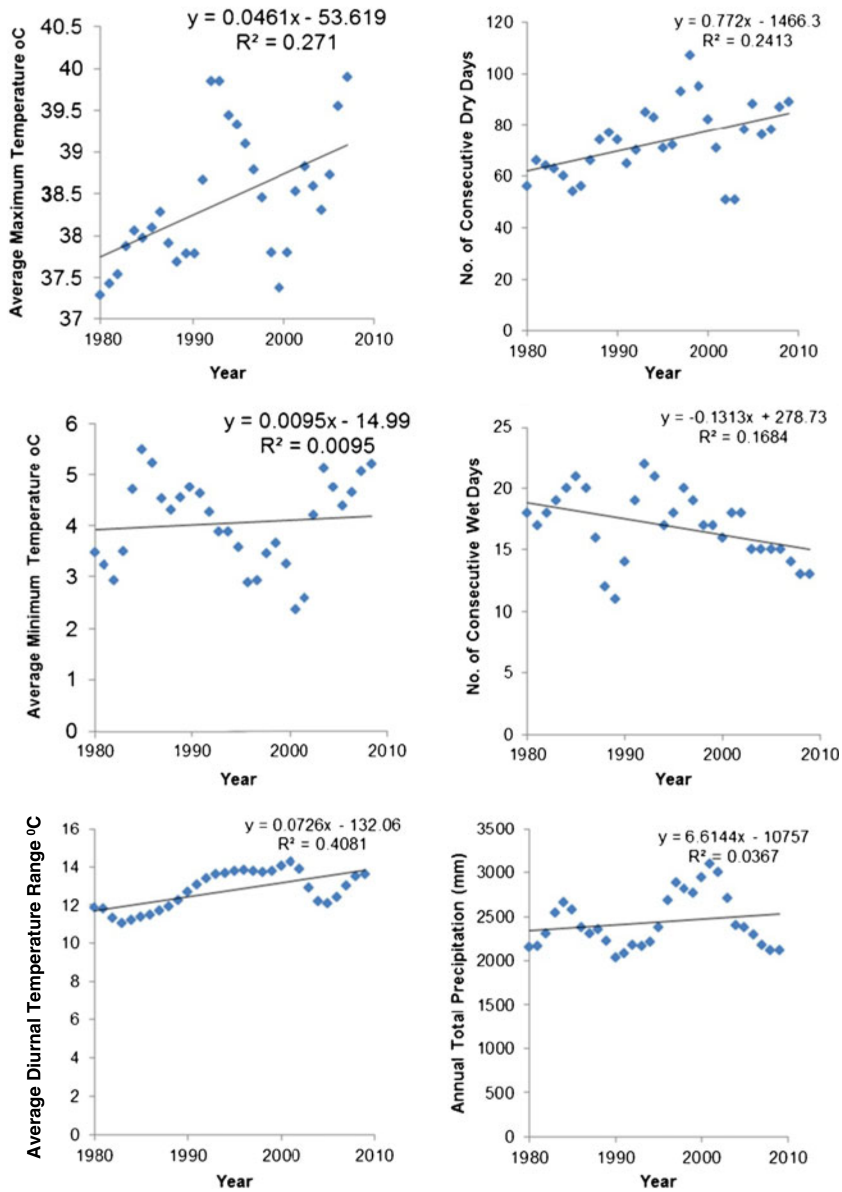

Fig. 2 Temperature and precipitation trends at Hetauda, Makwanpur district

days were reported by 79 % of VFS households and 89 % of CFS households. The opinions and responses of farmers, local experts and participants of the FGDs were good matches with the trend analysis of empirical temperature data.

With regard to rainfall, 87 % and 95 % of VFS and CFS households, respectively, thought that rainfall had increased in the last decade. During interviews, FGD and key informants reported that the intensity of rainfall was high during the monsoon and had been the cause of frequent floods and landslides in the study area. Farmers perceived that, in the past, rainfall was less intense but lasted longer, causing less damage to crops. Rainfall was high during the monsoon period but lately winter drought had become a major concern. According to those respondents who perceived changes in rainfall pattern, 85 % claimed a decreasing trend while 15 % claimed an increase. In the words of one local farmer, "*The onset of the monsoon is not on time and it is often erratic. In winter, the rain usually arrived after the wheat harvest in the past but it is now arriving before the harvest causing damage to the crop*". Thus farmers' perceptions are that rainfall has become more erratic and has increased in intensity, causing sporadic floods and landslides.

Food balance

The major food crops of the area are cereals, paddy rice in particular, and vegetables. Livestock keeping and fruit growing are practised by a limited number of farmers. District office data on demand and supply of food grains, mostly cereals, has shown a negative balance of food production in the district for the last several consecutive years (Fig. 3). The major crop in cereal-based farming areas is paddy rice with some wheat and vegetables as minor crops, whereas in vegetable-based

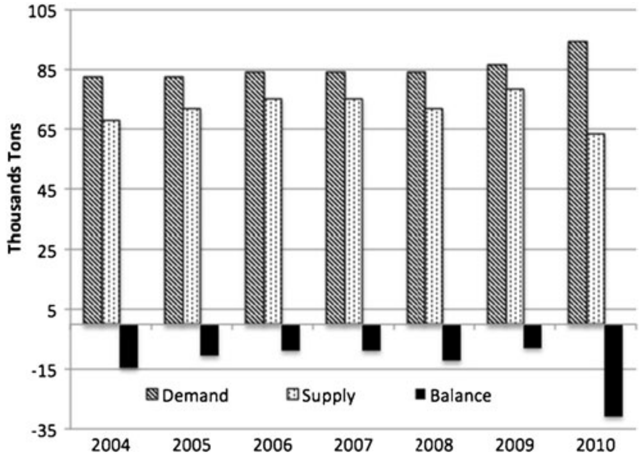

Fig. 3 Food demand and supply in Makawanpur district. Source: DADO (2010)

farming areas, vegetables are the major crops and maize, millet or wheat are minor crops.

Local farmers interviewed lamented that landslides, floods and droughts, during different periods of the year, caused difficulties for crop cultivation. Farmers, FGD participants and key informants reported that uneven rainfall negatively affected crop development and maturity, delayed crop desiccation and resulted in rotted crops and even grain and seed loss of standing crops. Floods in 1985, 1994, 2002, 2003 and 2005 and droughts in 2006, 2007 and 2009 were specifically mentioned. As a result, the food security, income and livelihoods of farmers' households were negatively affected. Other problems, such as stream bank erosion during heavy rains and landslides added further burdens to farmers by eating up already small land holdings, resulting in less land area for cultivation.

Food security

Food security is considered to be a flexible concept and hence its measurement can be not only difficult but also contextual. As food security is preferably measured at the household level, we considered simple variables as indicators to represent those pillars of food security, namely food availability, food accessibility, food utilization, and food system stability, mentioned in an earlier section of this paper to measure the impact of climate variability as perceived by the respondents.

With regard to crop area reduction, the impact was medium (3.1) in the case of CFS households compared to VFS households where it was low (2.0) as indicated by the food availability index (FAI; Table 2). More than half of VFS respondents (55 %) and CFS respondents (61 %) reported significant decreases in crop productivity. Of CFS respondents, 35 % changed cropping area from cereals to vegetables owing to reduced crop productivity, whereas 8 % VFS farmers changed from cereals to vegetables to cope with the adverse effect of climate change. Increasing drought and water scarcity, as climate change impacts, were felt to be at high and medium levels by VFS and CFS respondents, respectively.

Poor irrigation facilities in the area also negatively affected food availability through poor production. Nearly half of CFS farmers depend on irrigation of crop fields from rivers in addition to natural rain, unlike the VFS farmers who depend on natural rainfall alone. More than one third of surveyed households were also found to be practising rainwater harvesting for irrigation purpose in the area. This was done through community owned rainwater-harvesting ponds as shown in Fig. 4.

Two indicators, i.e. household income and food prices, were considered in order to examine the food accessibility of households. More than 90 % of respondents thought that the impact of climate variability had caused decreased income and simultaneously increased food prices, contributing to worsening of the food security situation. Impact on crop storage was felt at medium level by 93 % CFS respondents compared to low impact by 81 % VFS respondents as a consequence of having to maintain storage facilites. Farmers also cultivated a more limited number of crops or less diverse crop types in the study area and sold part of their agricultural produce in order to purchase foods that were not grown on their farms. Besides these constraints, VFS households also have difficulties in selling their products owing to the lack of transport, given the rugged and hilly terrain. The problem is especially acute during the rainy season because of roads and trails blocked by

Table 2 Farmers' response to the impact of climate change on food availability

Indicator	VFS (%HH)				CFS (%HH)				VFS	CFS
	H	M	L	NC	H	M	L	NC	FAI	
Reduced crop area	8	31	9	52	35	49	11	5	2.0	3.1
Reduced crop productivity	55	37	7	1	61	36	3	0	3.5	3.6
Increased drought and water scarcity	49	47	4	1	39	53	12	0	3.5	2.8
Increased food diversity	51	39	10	0	19	25	27	0	3.4	2.6
Crop storage	3	16	18	0	5	93	1	0	2.2	3.0
Disease/insect pests occurrence	15	33	52	0	9	54	37	0	2.6	2.7

H High, *M* Medium, *L* Low, *NC* No change; *FAI* (Food Availability Index): 4 = high impact, 3 = medium, 2 = low, 1 = no change; *HH* Household; *VFS* Vegetable-based farming system; *CFS* Cereals-based farming system

Fig. 4 **a** Rainwater harvesting pond, **b** Agroforestry, and **c** Straw mulching practised by VFS

landslides preventing access to markets. In contrast, CFS households, which are located in the plain area, had no landslide related problems. As vegetables are not staple foods, almost all CFS households sold their produce to meet other household expenses, including expenditure on food. More than 60 % of VFS households earned approximately 1500 US $ annually from the sale of vegetables. However, floods damaging VFS agriculture also affected CFS households as they are dependent on VFS for vegetables. Very few CFS households grew vegetables for home consumption.

VFS households perceived that they have higher food diversity to meet their dietary needs as shown by an FAI of 3.4 compared to an FAI of 2.6 for CFS households, who grow cereals and are constrained to grow vegetables due to biophysical unsuitability (Table 2). With regard to crop storage, the impact perceived was low (2.2) and medium (3.0) by VFS and CFS households, respectively because VFS households sold vegetables daily without storing because of the perishable nature of the crops. There was no significant difference between VFS and CFS households with regard to their perception of the occurrence of crop disease due to climate variability. Households from both areas felt that there was an increased incidence of disease and insects pests and their impact was perceived at medium level.

Food secure households were defined as households that never had to worry about food for the whole year. In order to analyze the self-sufficiency of food, households were categorized into four groups based on the period of food sufficiency from their own farm production using HFIAS as described earlier. About 37 % of VFS households and 27 % of CFS households were food secure (Table 3). Mildly food insecure households were defined as households that worried about not having sufficient food for fewer than 4 months a year, and/or were not able to eat preferred foods and/or had to eat the same food time and again, i.e. had a monotonous diet and/or had to eat foods not preferred by them but did not cut down the size of meals in terms. About 34 % VFS households and 21 % CFS households were mildly food insecure.

Moderately food insecure households are the ones that sometimes or often depend on monotonous foodstuffs, and/or eat few preferred foods, and/or seldom or occasionally reduce meal size but do not face a severe situation. There were 16 % VFS households and 23 % CFS households in this category. The households that frequently cut the size of meals and number of meals each day and/or experienced several severe circumstances were categorized as severely food insecure households. There were 13 % VFS and 29 % CFS households in this category. These households also did not have enough foodstuffs purchased from the market to meet their food needs. Farmers with larger land holdings and smaller household size in general were found to be more food secure than farmers with smaller land holdings and larger household size. Assuming secure as a score of 1 and severely insecure as a score of 4, the food insecurity index of 2.5 for CFS indicates that these households have anxiety about food security for about six months a year compared to VFS households (2.1) who felt food insecure for about four months a year.

Adaptation measures to reduce the impact of climate change

Studies suggest that despite the differences in climate related risks of flood and landslides, farmers practise local level adaptation processes to reduce the climate risk (Swe et al., 2014;

Table 3 Food insecurity of farm households

Insecurity Category	VFS %HH	CFS
Secure	37	27
Mildly insecure (insufficient food for <4 months a year)	34	21
Moderately insecure (insufficient food for 4–8 months a year)	16	23
Severely insecure (insufficient food for 8–12 months a year)	13	29
Insecurity index	2.1	2.5

Index: 4 = severely insecure, 3 = moderately, 2 = mildly, 1 = secure; *HH* Household; *VFS* Vegetable-based farming system; *CFS* Cereals-based farming system

Jianjun et al., 2015). In our study area, farmers have incorporated several adaptation measures in their farming practices to cope with these risks. These include both changes in on-farm traditional agricultural practices and off-farm practices, such as forest protection and off-farm employment (Table 4). In order to compensate for climate change, 90 to 95 % of respondents of both vegetable and cereal farmers applied chemical fertilizers and changed crop varieties. Some of the measures were significantly different between the VFS and CFS, such as rainwater harvesting (80 % and 37 %, respectively) and agroforestry (86 % and 21 %, respectively). On the other hand, the great majority (93 %) of CFS households had off-farm employment compared to only 61 % of VFS households.

Increased temperature and erratic rainfall resulted in low productivity of the crops, and hence most respondents have shifted from producing cereals to vegetable crops. According to the VFS respondents, it is relatively easier to cultivate vegetables despite the changing climate, as they are able to implement various technologies to control the environment and thus risk. These include plastic tunnels and raised bed cultivation, which are almost impossible for cereal crop cultivation. The majority of farmers reported having changed crops variety to better cope with the impact of changing climate. Local varieties have been replaced by new hybrids which are better suited to withstand floods and droughts. Altogether 92 % of households reported to have changed crop varieties since the year 2000 although this change was not solely a response to climate change or variability. The other reasons cited for change were increased yield and early maturation of the crop.

Farmers also started making modifications to the traditional cropping calendar owing to variation in temperature, rainfall, relative humidity as well as changes in crop varieties (Fig. 5). Almost all the respondents mentioned that the planting time of major cereal crops such as paddy, maize, wheat and finger millet has changed in the last 10 years with delayed planting and harvesting by half to one month in the case of most lowland and upland crops.

Table 4 Adaptation measures

Measures	VFS % HH	CFS
Rain water harvesting	80	37
Changes in crop varieties	90	95
Chemical fertilizer use	93	90
Organic manure use	67	60
Agroforestry	86	21
Forest protection	77	78
Off-farm employment	61	93

HH Household, *VFS* Vegetable-based farming system, *CFS* Cereals-based farming system

Most farmers reported using organic and chemical fertilizers in greater amounts compared to earlier years in efforts to increase or maintain productivity. Soil erosion leads to nutrient leaching and thus forces farmers to apply increased amounts of fertilizers (Rohlini et al., 2007). In our study area, the reason given for the increased application rate of fertilizers was the loss of soil fertility due to drier soils, increased erosion, and nutrient leaching from increased temperature and rainfall. However, according to one farmer, crop yield was good and enough to feed the entire family although less fertilizer was applied than 15 years previously.

In addition to increasing incidence of diseases and insect pests, farmers have also witnessed increases in weed populations. However, no farmers used herbicides, possibly because of being unaware of them but also because weeds can be used as livestock feed and bedding material. In addition, agroforestry is mostly limited to cultivated fodder species for livestock. Given the hilly terrain, the majority of VFS households have adopted agroforestry, growing such species as Mulberry, Napier and Broom grass, in order to minimize soil erosion and landslides on the steep slopes. Besides, some agroforestry species have economical value as they can be sold in the market.

The majority of respondents reported that under growing climatic uncertainty, off-farm employment has helped farmers to improve their food security situation. More than three-quarters of households in both categories had actively engaged in forest protection due to their increasing awareness of the importance of forests in the contexts of soil and water conservation, landslide control, and harvest of appropriate forest products for efficient resource use (Niraula et al. 2013). It is worth citing here that Nepal has successful participatory forest management (Ojha et al., 2009).

Agricultural production has been rapidly declining in Nepal and households have no choice other than to seek alternative sources of income. About 40 % of the households surveyed worked as off-farm agricultural labor followed by employment in the service sector and small businesses. Only 3 % of the respondents reported that they still solely depended on agriculture for their livelihoods. Another important factor is that only 15 % of males and 8 % of females had pursued or were pursuing higher education. Low education level is a major barrier to obtaining employment outside the agricultural sector. Land was the primary physical asset of households in the study area and it is common practice for land to be used as collateral in order to acquire bank loans. These were mainly used for agricultural activities, such as buying seeds, fertilizers and equipment for irrigation, and even meeting the cost of travel in order to send family members abroad for foreign employment in some cases. Migration of male members to foreign countries including India and Malaysia for employment is common in the area in order to cope with food insecurity and economic hardship. Most migrants were from

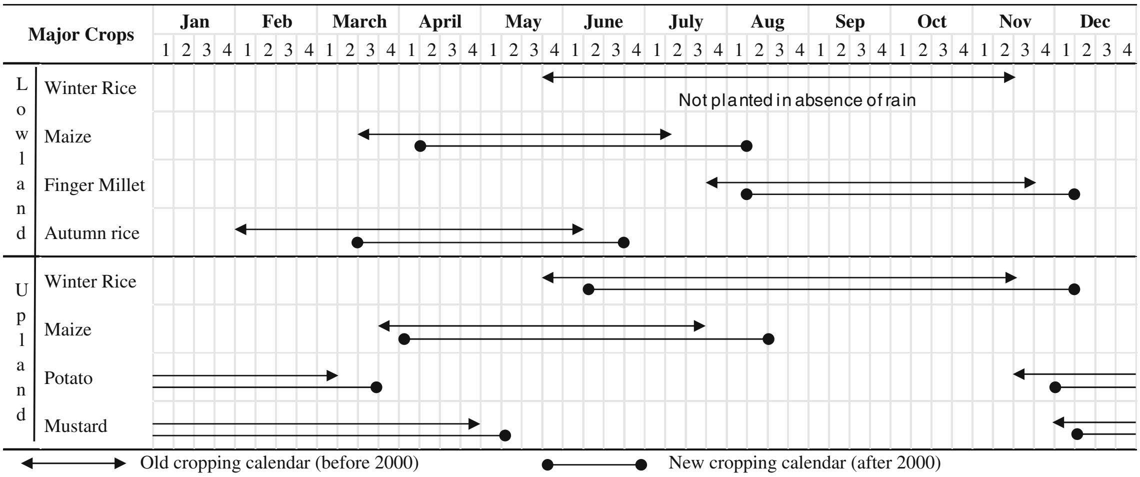

Fig. 5 Old and new cropping calendar

households with insufficient access to food, unemployed or were burdened with debts.

Conclusions and policy implications

This study shows that there have been changes in temperature and rainfall patterns in the study area in the recent past with slightly increased temperature although less than the national average and fewer wet days. These results are consistent with farmers' opinions. Farmers reported a range of impacts of climate change on crop productivity, which eventually forced them to alter their traditional cultivation practices. Major impacts included increased outbreaks of insect pests, weeds and crop diseases, and decline in soil quality. These have led to increased use of pesticides and fertilizers and adoption of measures such as use of high yielding varieties and change of cropping patterns and calendar in order to maintain crop production levels. However, these adaptation measures have done little to increase farm productivity and food insufficiency continues to exist, the majority of households having experienced some level of food insecurity. Both vegetable-based and cereal-based subsistence farmers are food insecure for about half of the year, however, the former group is more secure as there is higher food diversity, more regular source of income from diverse farm products and relatively fewer climate extremes at their location. Farmers with larger land holdings and smaller household size in general were more food secure than farmers with smaller land holdings and larger household size.

Farm households are increasingly looking for other options to cope with declining and variable farm production. Off-farm employment, taking out loans and even out-migration within the country and abroad are prevalent practices for adapting to economic hardship. Besides several constraints, such as reliance on natural rainfall, small land holdings, frequent floods and droughts, poor transport infrastructure, difficult terrain, low levels of education and widespread poverty, the actual impacts of climate change and variability are also largely dependent on farm and household characteristics, which influence management and adaptation (Reidsma et al., 2010). In this study, vegetable-based households seemed better able to cope and absorb climate variability than cereal-based ones. The former group also have comparatively higher literacy rates, less off-farm employment, more irrigation facilities but lower mechanization. Transformation from a household's needs-based cereal production system to market-oriented vegetable production can be seen as financially advantageous and also a means to better coping with adverse climate conditions and food insecurity (Dahal et al. 2009).

This study clearly suggests that agricultural productivity will have to improve in order to ensure food security. Enhancing water use efficiency is a critical response to climate risks (Iglesias et al. 2012) as practised by VFS farmers through rainwater harvesting. Agro-forestry, mulching, adjusting growing time, and improving off-farm income opportunities can contribute both directly and indirectly to crop production and improved food security. There is also a need for improving support services for farming activities, such as information access, infrastructure, extension and market and storage facilities. This requires substantial efforts at community and household levels (Wahlqvist et al. 2012). Although this study is based on the perception of farmers, it has generated useful information on food insecurity attributable to climate risks at the household level and has furthermore shown that food security in terms of a nourishing diet for individuals within a household is subject to variation that justifies further investigation and empirical studies.

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Compliance with ethical standards

Conflict of interest We authors declare that there is no conflict of interest with the Asian Institute of Technology.

References

Baidya, S. K., Shrestha, M. L., & Sheikh, M. M. (2008). Trends in daily climatic extremes of temperature and precipitation in Nepal. *Journal of Hydrology and Meteorology*, *5*(1), 38–51.

Barett, C. B. (2002). Food security and food assistance programs. Gardener B.L. & Rausser G.C. (Eds.), *Handbook of Agricultural Economics* (pp. 2–75). Elsevier Science, Amsterdam.

Bhandari, D. (2008). Food security amidst climate change in Nepal. *Mountain Forum Bulletin*, *8*(1), 21–24.

Bryant, C. R., Smit, B., Brklacich, M., Johnston Thomas, R., Smithers, J., Chiotti, Q., & Singh, B. (2000). Adaptation in Canadian agriculture to climatic variability and change. *Climate Change*, *45*, 181–201.

Carletto, C., Zezza, A., & Banerjee, R. (2013). 2013. towards better measurement of household food security: harmonizing indicators and the role of household surveys. *Global Food Security*, *2*, 30–40.

CBS (2005). *District Profile of Makwanpur*. Kathmandu: Central Bureau of Statistics.

Coates, J., Swindale, A., & Bilinsky, P. (2007). *Household Food Insecurity Access Scale (HFIAS) for measurement of food access: Indicator Guide, version 3, Food and Nutrition Technical Assistance Project (FANTA)*. DC: Washington.

Codjoe, S., & Owusu, G. (2011). Climate change/variability and food systems: evidence from the African Plains, Ghana. *Regional Environmental Change*, *11*(*4*), 753–765.

Dahal, B, M., Nyborga, I., Sitaula, B. K., & Bajracharya, R. M. (2009). Agricultural intensification: food insecurity to income security in a mid-hill watershed of Nepal. *International Journal of Agricultural Sustainability, 7*(4), 249–260.

DHM (2005). *Climate Datas 1975–2005*. Nepal: Nepal Department of Hydrology and Meteorology (DHM), Kathmandu.

Easterling, W.E., Aggarwal P.K., Batima, P., Brander, K.M., Erda, L., Howden, S.M., Kirilenko, A., Morton, J., Soussana, J.F., Schmidhuber, J., & Tubiello, F.N. (2007). Food, fibre and forest products. Parry, M.L., Canziani, O.F., Palutikof, J.P., Linden, P.J., Hanson, C.E. (Eds.), *Climate Change 2007*: *Impacts*, *Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 273–313). Cambridge: Cambridge University Press.

FAO (2003). *Trade and Reforms and Food Security: Conceptualizing the Linkages*. Rome: Food and Agriculture Organization.

FAO (2008). *Climate Change and Food Security: A Framework Document*. Rome: Food and Agriculture Organization.

Gentle, P., & Maraseni, T. N. (2012). Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental Science & Policy*, *21*, 24–34.

Iglesias, A., Quiroga, S., Moneo, M., & Garrote, L. (2012). From climate change impacts to the development of adaptation strategies: challenges for agriculture in Europe. *Climate Change*, *112*(1), 143–168.

IPCC (2007). *Contribution of working group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, impacts, adaptation and vulnerability, Climate Change 2007*. Cambridge, UK: Cambridge University Press.

IPCC, 2012: Summary for policymakers. In: Managing the risks of extreme events and disasters to advance climate change adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, P.M. Midgley (eds.)]. *A special report of working groups I and II of the Intergovernmental Panel on Climate Change* (pp. 1–19). Cambridge University Press, Cambridge, UK, and New York, NY, USA.

Jianjun, J. and G. Yiwei, W. Xiaomin, & Nam, P.K. 2015. Farmers' risk preferences and their climate change adaptation strategies in the Yongqiao District, China, *Land Use Policy*, 47, 365–372.

Jones, L., & Boyd, E. (2011). Exploring social barriers to adaptation: Insights from Western Nepal. *Global Environmental Change*, *21*, 1262–1274.

Lasco, R. D. & R. Boer, 2006. *An Integrated Assessment of Climate Change Impacts*, *Adaptations and Vulnerability in Watershed Areas and Communities in Southeast Asia* (AIACC, Washington, DC), Final Report Project No. AS 25.

Li, C., Tinga, Z., & Rasaily, R. G. (2010). Farmer's adaptation to climate risk in the context of China-A research on Jianghan Plain of Yangtze River basin. Beijing, *Agriculture and Agricultural Science Procedia*, *1*, 116–125.

Malla, G. (2008). Climate change and its impact on Nepalese agriculture. *The Journal of Agriculture and Environment*, *9*, 62–79.

Misselhorn, A. A. (2005). What drives food insecurity in Southern Africa? a meta-analysis of household economy studies. *Global Environmental Change*, *15*, 33–43.

MoAC, W. F. P., & FAO (2009). *Crop and food security assessment: Joint assessment report*. World Food Program and Food and Agriculture Organization, Kathmandu: Ministry of Agriculture and Cooperatives.

MoAC (2010). *Selected indicators of Nepalese agriculture and population*. Kathmandu: Ministry of Agriculture and Cooperatives.

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceeding of the National Academy Of Sciences.*, *104*(50), 19680–19685.

Niraula, R. R., Gilani, H., Pokhrel, B. K., & Qamer, F. M. (2013). Measuring impacts of community forestry program through repeat photography and satellite remote sensing in the dolakha district of Nepal. *Journal of Environmental Management*, *126*(15), 20–29.

NRC, 2010. Advancing the Science of Climate Change. National Research Council. The National Academies Press, Washington DC, USA.

Ojha H., Persha L, & Chhatre, A. (2009) Community forestry in Nepal: a policy innovation for local livelihoods. IFPRI International Food and Policy Research Institute. Discussion Paper 00913.

Regmi, B. R., Thapa, L., Sharma, G. B., & Khadka, S. (2008). *Climate change risk, vulnerability and adaptation strategies at community level*. Pokhara, Nepal: LIBIRD.

Regmi, B. R., & Adhikari, A. (2007). *Human Development Report 2007 (Climate change and human development- risk and vulnerability in a warming world) Country case study- Nepal*. Kathmandu: United Nation Development Program.

Reidsma, P., Ewert, F., Lansink, A. O., & Leemans, R. (2010). Adaptation to climate change and climate variability in European agriculture: The importance of farm level responses. *European Journal of Agronomy*, *32*, 91–102.

Rohlini, H., Clemente, R. S., Routray, J. K., & Shrestha, R. P. (2007). Integration of biophysical and socioeconomic factors to assess soil erosion hazard in the upper kaligarang watershed, Indonesia. *Land Degradation and Development*, *18*, 453–469.

Rowhani, P., Lobell, D. B., Linderman, M., & Ramankutty, N. (2011). Climate variability and crop production in Tanzania. *Agricultural and Forest Meteorology*, *151*, 449–460.

Ryan, C., & Garland, R. (1999). 1999. the use of a specific non-response option on likert-type scales. *Tourism Management*, *20*, 107–113.

Schmidhuber, J. & Tubiello, F. N. (2007). Global food security under climate change, *PNAS*, 1 04 (50),19703–19708.

Shrestha, A. B., Wake, C. P., Mayewski, P. A., & Dibb, J. E. (1999). Maximum temperature trends in the Himalaya and its vicinity. An analysis based on temperature records from Nepal for the period 1971-94. *Journal of Climate*, *12*(9), 2775–2787.

Smit, B., & Skinner, M. (2002). Adaptation options in agriculture to climate change: a typology. *Mitigation and Adaptation Strategies for Global Change*, *7*, 85–114.

Swe, L. M. M., Shrestha, R. P., Ebbers, T., & Jourdain, D. (2014). The farmers' perception and adaptation to climate change impacts in dry zone of Myanmar. *Climate and Development*, *7*(5), 437–453.

Vermeulen, S. J., Aggarwal, P. K., Ainslie, A., Angelone, C., Campbell, B. M., Challinor, A. J., Hansen, J. W., Ingram, J. S. I., Jarvis, A., Kristjanson, P., Lau, C., Nelson, G. C., Thornton, P. K., & Wollenberg, E. (2012). Options for support to agriculture and food security under climate change. *Environmental Science and Policy, 15(1)*, *136-144*.

Wahlqvist, M. L., McKay, J., Chang, Y., & Chiu, Y. (2012). Rethinking the food security debate in Asia: some missing ecological and health dimensions and solutions. *Food Security*, *4*, 657–670.

WFP & NDRI (2010). *The Food security atlas of Nepal*. Kathmandu: National Planning Commission.

World Bank (2002). *World Development Indicators*. Washington DC: World Bank.

Yamane, T. (1967). *Statistics: An Introductory Analysis* (2nd ed.,). New York: Harper and Row.

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