Climate risk and food security in Nepal—analysis of climate impacts on food security and livelihoods

Working Paper No. 48

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

P.K. Krishnamurthy, C. Hobbs, A. Mathiassen, S.R. Hollema, R.J. Choularton, K. Pahari, M. Kawabata

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Photos:
Photographs 1–3. World Food Programme/James Giambrone.
Photograph 4. World Food Programme/Deepesh Shrestha.

Abstract

Food security in Nepal is highly sensitive to climate risks. Recent climate-related events, such as the floods of 2008 and the winter drought of 2008/2009, have highlighted the potential impacts of climate on food production, access to markets and income from agricultural activities. However, the ways in which livelihoods and other vulnerabilities are linked to climate have not been well studied. The purpose of this analysis is to quantitatively and qualitatively assess climate (including climate variability, change and extremes) impacts on food security and livelihoods. The analytical method carried out for this research consisted of three components: (i) a dynamic analysis to evaluate the relationship between historic and current climatic variability and food security indicators, using long-term historical data; (ii) a descriptive analysis to establish a baseline against which vulnerability to future risks can be assessed, using household data from the Nepal Living Standards Survey 2010/2011 (NLSS-III); and (iii) a workshop with national stakeholders to validate the results and identify priority adaptation interventions.

Keywords

Climate risk; food security; Nepal.

About the authors

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Acronyms

CBS	Central Bureau of Statistics
DFID	(UK) Department for International Development
DHM	Department of Hydrology and Meteorology
DWIDP	Department of Water Induced Disaster Prevention
FAO	(UN) Food and Agriculture Organization
FCS	Food consumption score
GCM	General circulation model
GHI	Global Hunger Index
GLOF	Glacial lake outburst flood
HPI	Human Poverty Index
ICIMOD	International Centre for Integrated Mountain Development
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
LSMS	Living Standards and Measurement Study
MoAC	Ministry of Agriculture and Cooperatives
MoE	Ministry of Environment
NAPA	National Adaptation Programme of Action
NARC	Nepal Agricultural Research Council
NCEP	(US) National Centers for Environmental Prediction
NDRI	Nepal Development Research Institute
NeKSAP	Nepal Food Security Monitoring System
NLSS	Nepal Living Standards Survey
NPC	National Planning Commission
NPR	Nepalese rupees
OCHA	(UN) Office for the Coordination of Humanitarian Affairs
RCM	Regional circulation models
SRI	System of rice intensification
UNDP	United Nations Development Programme
WFP	World Food Programme

Introduction

This report presents the findings of an analysis carried out to identify relationships between climate variables and food security indicators. The analysis has three main objectives:
(1) to identify spatial and temporal relationships between food security and climate variables by correlating, on the national and sub-national scales, the long-term data series of food security indicators (crop yields, food prices, livestock product output) and climate parameters (precipitation and temperature); (2) to establish a vulnerability baseline in order to assess the factors that render a household vulnerable to climate variability; and (3) to identify a set of key policies to build adaptive capacity and reduce climate-related food insecurity in the most vulnerable communities.

National context

Demographics

Nepal is a land-locked country with a population of around 27 million (Central Bureau of Statistics (CBS), 2012). The topography of Nepal is very complex[1], and is generally divided into three physiographic areas (ecological belts): the southern lowland plains (Terai); the hill region with an altitude that varies from approximately 800 to 4000 metres; and the mountain region, towards the north of the country, which includes areas at an altitude higher than 4000 metres. These three zones run from east to west (figure 1).

Nepal is also divided into 5 Development Regions (Far-Western, Mid-Western, Western, Central, and Eastern), which in turn are divided into 14 administrative zones and 75 districts (figure 1).

The map shows the three ecological belts (Terai, hills and mountains) as well as the 5 Development Regions of Nepal. Each Development Region contains the 3 main physiographic features of Nepal.

The distribution of population is uneven across the country. Urban areas, particularly the capital Kathmandu, are more densely populated, followed by the eastern Terai. Mountain areas are less densely populated, particularly in the Mid- and Far Western Development Regions. This is because the environment tends to be sensitive and less productive there (figure 2).

Figure 1. Ecological belts and development regions of Nepal.
(Source: CBS, 2011)

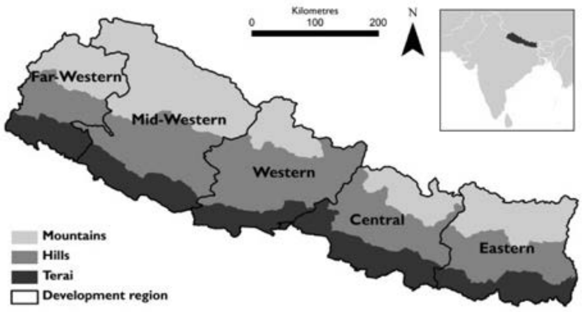
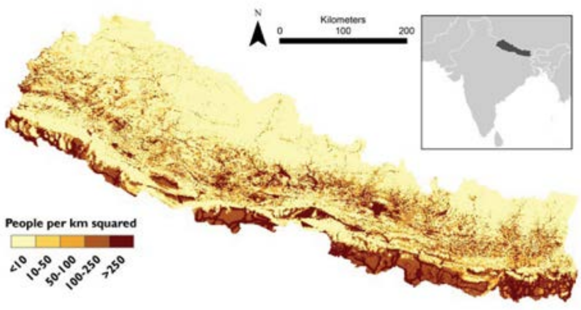


Figure 2. Population density in Nepal, 2010/2011.
(Source: LandScan, 2011)



1 The varied topography of Nepal adds a layer of complexity to any climate vulnerability analysis.

The map shows population density (persons per km²) at a resolution of 30 arc-seconds. The most densely populated areas are in urban centres (particularly Kathmandu) and the Terai. The least densely populated areas are in the Mid- and Far Western mountain areas of Nepal.

While the population has grown significantly in the past few decades, increasing agricultural production to a satisfactory level has remained a challenge in addressing poverty and food insecurity in Nepal. Since the introduction of malaria-control measures in the 1950s, the most significant population increase has been in the Terai due to migration from the hill and mountain regions. Outside of the Terai, urban areas (especially Kathmandu) have experienced significant population growth associated with migration from different parts of the country (figure 3).

The map shows population growth at district level in Nepal, with darker colours indicating higher growth rates. It highlights that population growth is generally highest in the Terai, while it is decreasing in the eastern mountains and hills.

Poverty incidence at sub-regional level

Poverty remains a predominantly rural phenomenon—in 2010/2011 almost 28% of the population in rural areas were poor compared to 15% of the urban population. The Eastern, Central and Western Development Regions have a poverty incidence level below the national average, whereas the Mid- and Far Western Development Regions have poverty rates above the national average. The Terai region has the lowest incidence of poverty (23%, compared to 42% in the mountains and 24% in the hills). The incidence of poverty varies significantly across the country, ranging from 8.7% in the urban hills to 42.3% in the mountains (figure 4).

Figure 3. Population growth in Nepal, 2001/2011.
(Source: CBS, 2011)

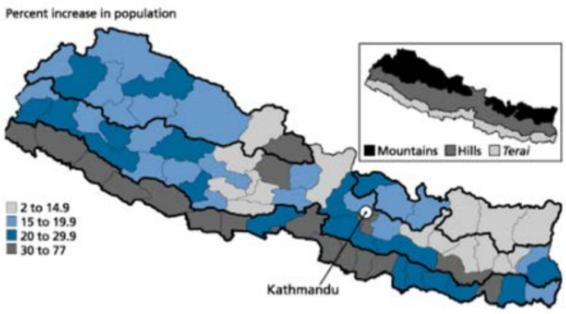
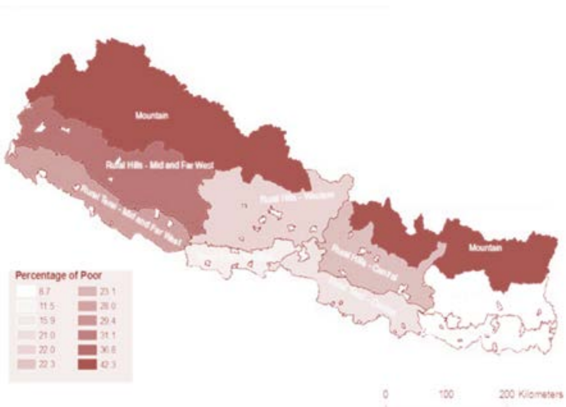


Figure 4. Poverty incidence at sub-regional level, 2006.
(Source: CBS, 2011)



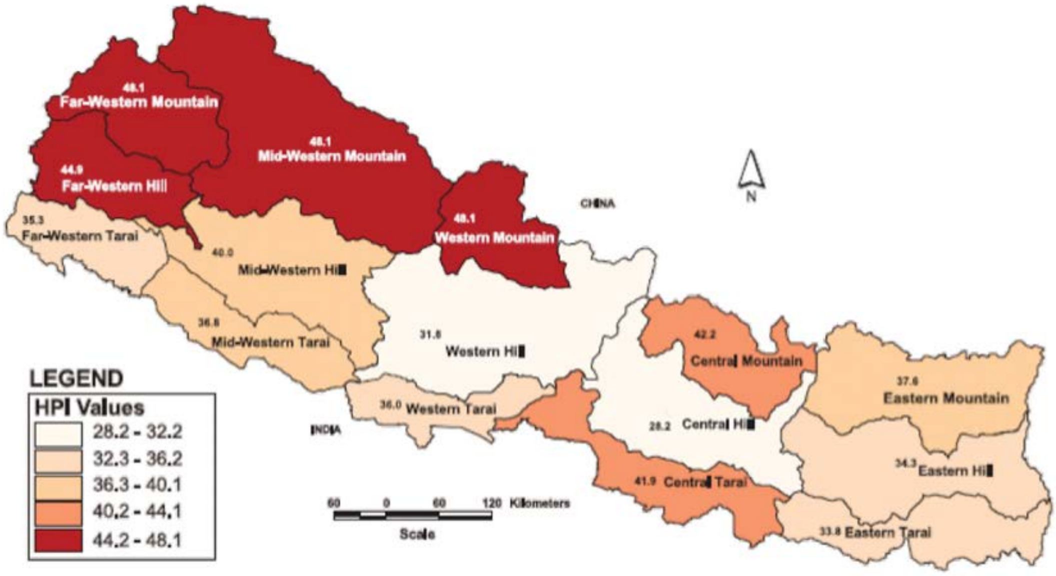
The map highlights the incidence of poverty (that is, the proportion of the population considered to be below the poverty line) at sub-regional level. It shows that the lowest levels of poverty incidence occur in the eastern Terai. The highest levels of poverty occur in the mountains, as well as in the Mid- and Far Western Development regions.

Significant progress has been made to reduce poverty in Nepal. According to the CBS (2005 and 2012), national poverty levels declined from 42% in 1995/1996 to 31% in 2003/2004 and further still to 25% in 2010/2011. The most significant progress was made in urban areas (excluding Kathmandu), where poverty levels declined by more than 60% over the same period. This decrease in the incidence of poverty can be broken down regionally as follows: in the rural eastern Terai by 33%; in the rural western hills by 32%; in Kathmandu by 23%; and in the rural western Terai by 17%.

Other measures of poverty, such as the Human Poverty Index (HPI)—a measure of life expectancy, access to basic education and access to public and private resources—highlight that, despite significant progress, the Western Development Regions of Nepal remain deprived and are therefore less able to cope with food security and climate-related shocks (figure 5).

The HPI is a measure of life expectancy, access to basic education and access to public and private resources. National HPI scores for Nepal have declined from 39.6 in 2011 to 35.4 in 2006. The largest decline occurred in the mountain and hill areas. However, despite Government policies of balanced regional development, the regions most deprived in the past remain deprived today.

Figure 5. HPI across eco-development regions of Nepal, 2006.
(Source: United Nations Development Programme (UNDP), 2009a)



Food security context

Despite significant development improvements in recent years, Nepal is a highly food insecure country—estimates suggest that approximately 38% of the country's population is energy deficient (National Planning Commission (NPC) and CBS, 2013). Nepal is influenced by the summer monsoon and agriculture is predominantly rainfed, depending heavily on monsoon rains (Shrestha et al., 2000). Increasingly erratic rainfall patterns over the last few decades (Parthasarty et al., 1992; Staubwasser et al., 2002) and a perceived decline in precipitation, especially in food deficit areas after the 1960s (Kothyari and Singh, 1996), suggest that continued climate variability could have a detrimental effect on food security in the country. The combination of consecutive winter droughts and a poor monsoon in 2008/2009, which affected 3.4 million people, illustrates the sensitivity of food security to climate in Nepal (Oxfam, 2011).

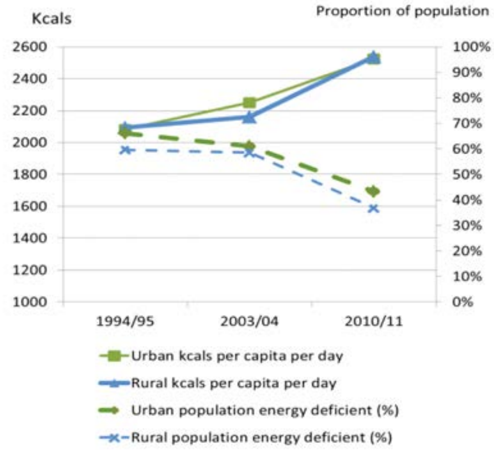
More than half of the population in Nepal lives in hill and mountain regions, where socioeconomic and agricultural development has been neglected. The majority of people living in these areas rely on agricultural imports. It is estimated that rural populations in these regions spend up to 78% of their income on food (World Food Programme (WFP) and Nepal Development Research Institute (NDRI), 2010), making them highly vulnerable to price volatility.

Food security trends

Despite an increase in the number of undernourished people in Nepal, the prevalence of undernourishment has decreased steadily since 1991 (Food and Agriculture Organization (FAO)/WFP, 2010; NPC and CBS, 2013; figure 6). Social and human development indicators, such as life expectancy, and infant and maternal mortality rates have improved considerably in the same time (UNDP, 2010). Datasets from the Nepal Living Standards Survey 2010/2011 (NLSS-III) show that food security measures have generally improved across the country, with households consuming more kilocalories and a more diverse diet than in previous years.

The graph shows the trend in the proportion of people that are energy-deficient (in terms of caloric intake) in urban (green) and rural areas (blue). In 2003–2011, the increase in average caloric consumption and decline in the proportion of the population living below the minimum caloric threshold was slightly greater in rural areas.

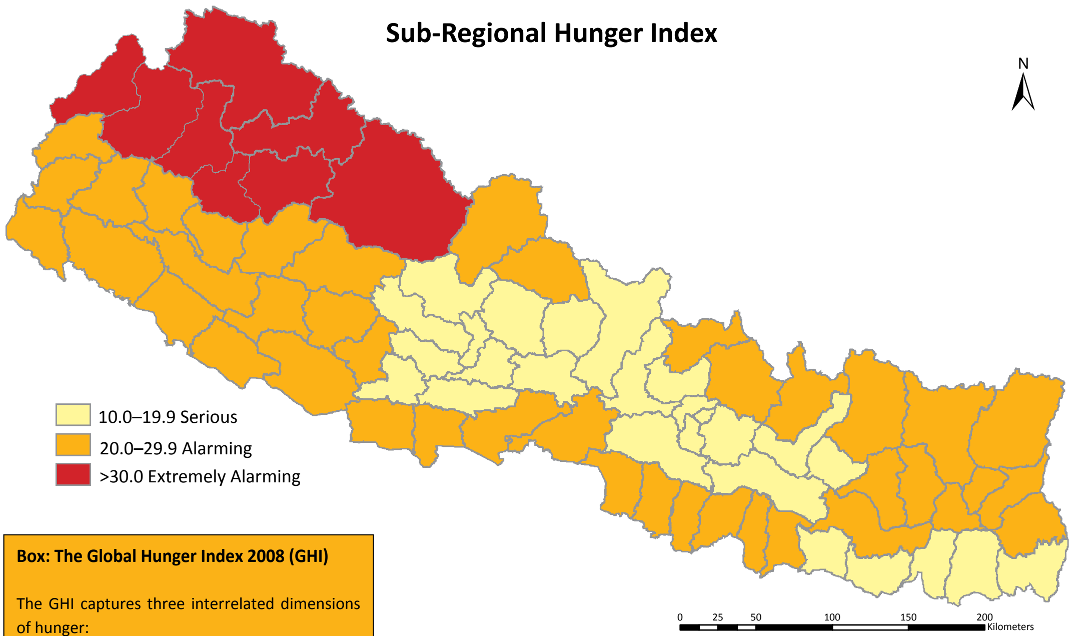
Figure 6. Food security trends in Nepal, 1994–2011.
(Sources: NPC and CBS, 2013)



However, despite these positive trends, Nepal remains one of the poorest and most food insecure countries in Asia (UNDP, 2011). In recent years, the combination of climate-related disasters, high food prices and low economic growth has resulted in higher food insecurity in the most vulnerable communities, particularly in western Nepal (figure 7). The mid-western mountain regions have some of the worst hunger rates in the world (WFP and NDRI, 2010), highlighting the spatial differences in vulnerability across the country.

The map shows the hunger rates in the different regions of Nepal using a Global Hunger Index (GHI) from the International Food Policy Research Institute (IFPRI). The results show that the most vulnerable and food insecure communities live in the western Himalayan region of Nepal. The GHI is calculated by combining three factors: (i) proportion of population undernourished; (ii) prevalence of underweight children under the age of 5; and (iii) mortality rate in children under 5. A higher index score indicates higher hunger risk (IFPRI, 2008).

Figure 7. Sub-regional hunger rates in Nepal, 2008.
(Sources: WFP and NDRI, 2010)



Box: The Global Hunger Index 2008 (GHI)

The GHI captures three interrelated dimensions of hunger:

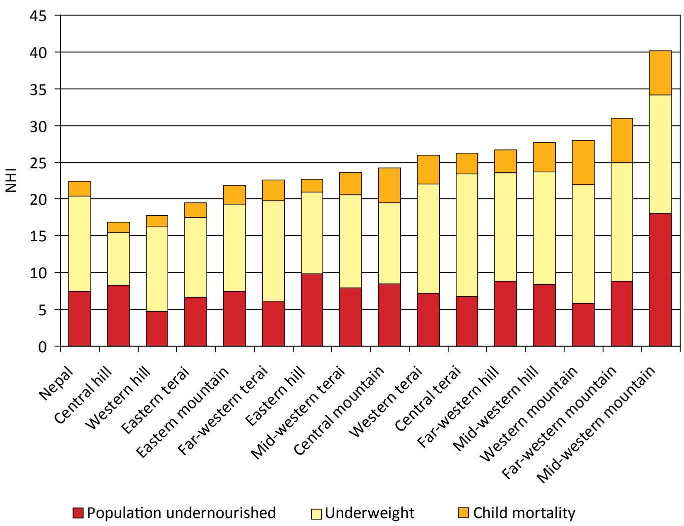
1. Insufficient availability of food, measured in *percentage of population undernourished,*
2. Shortfalls in the nutritional status of children, measured in *prevalence of underweight in children under the age of five* and
3. Child mortality, measured as the *mortality rate of children under the age of five.*

The index is derived by simply taking the un-weighted average of these three interrelated indicators.

A higher index indicates a higher prevalence of hunger. The severity of hunger is determined using the following thresholds:

GHI ≤ 4.9	low
GHI 5.0-9.9	moderate
GHI 10.0-19.9	serious
GHI 20.0-29.9	alarming
GHI ≥ 30.0	extremely alarming

The Global Hunger Index is developed by the International Food Policy Research Institute (IFPRI).



Climate trends

Weather station data indicate an increase in temperature trends across Nepal in the period 1975–2009 (Department of Hydrology and Meteorology (DHM), 2010; McSweeney et al., 2010; figure 8). Other studies using instrumental record data suggest an increase in temperature in recent years, particularly in the northwestern Himalayan region (Bhutiyani et al., 2010). Spatial distributions of temperature trends in Nepal show high variations across the country. In most of the Himalayan region and the middle mountains there has been rapid warming, while in the Terai and Siwalik regions there has been a cooling trend. Communities in the Himalayan region have also perceived an elongation of the summer season and a shortening of winter. In contrast, people in the Terai have reported a longer and colder winter season in recent years (Gurung et al., 2010).

Overall temperatures have increased by around 1.5 °C in Nepal over the period 1975–2009. This trend is not uniform across the year or across the country. The majority of this increase has taken place during the dry season (December to March), especially in the Himalayan regions where the average temperature has increased by 2 °C since 1970.

Gridded station precipitation data in Nepal shows high inter-annual and inter-decadal precipitation variability (cf. Shrestha et al., 2000) although an overall decline has been observed in the period 1960–2005 (McSweeney et al., 2010; figure 9). However, the inter-annual variability in rainfall is so large that it is difficult to ascertain long-term trends associated with anthropogenic climate variability alone (Practical Action, 2009; Ministry of Environment (MoE), 2010). In spite of the difficulty in identify trends through weather station data, communities in the Himalayan and hill regions have observed a change in the type of precipitation—from snow to rain. Communities have also reported that the duration and magnitude of winter drought have increased in recent years compared to the 1980s and 1990s, while the intensity of monsoon rains has increased and the timing of rains has become increasingly erratic and unpredictable, with implications on livelihoods and food security, again, compared to the 1980s and 1990s (Gurung et al., 2010).

An analysis of precipitation anomalies, measured as differences from the long-term mean, shows that rainfall over the whole country has decreased since 1960 but there is high inter-annual variability. This decrease has largely been due to a decline in mean precipitation during

Figure 8. Mean temperature trends in Nepal (average from weather stations in the whole country), 1975–2005.

(Sources: McSweeney et al., 2010; DHM, 2010)

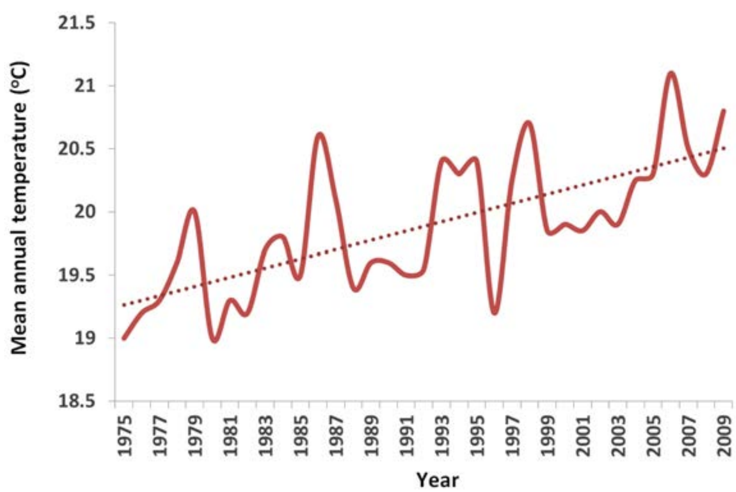
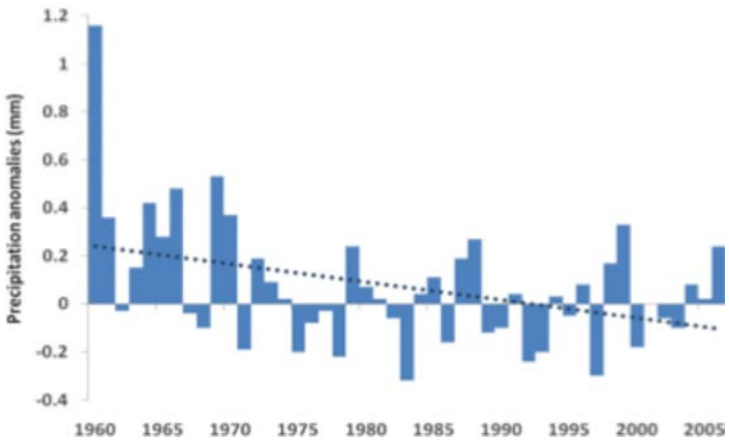


Figure 9. Precipitation anomaly trends in Nepal (average of the whole country), 1960-2005.
(Sources: McSweeney et al., 2010)



the dry season (December to February). However, precipitation trends are particularly difficult to evaluate due to large inter-annual variations in monsoon rains and topography.

Climatology in Nepal is largely influenced by the complex topography of the Himalayan mountain range. The main rainy season is during the monsoon (June to September). Monsoon rain is most abundant in the eastern and central parts of the Nepal, and gradually declines as it moves westwards (figure 10). The driest part of the country includes the mountain areas of the western regions, coinciding with the highest food insecurity rates.

The map highlights that the mountain areas of the Western, Mid-Western, and Far Western Development Regions of Nepal receive the least rainfall. In contrast, the area around Pokhara and the eastern Terai tends to receive more rainfall.

The relatively dry conditions in the Western Himalayan region have influenced the choice of crops and livestock—drought-tolerant crops such as millet are grown by more households in the western Himalayan region than in other regions of the country. Similarly, livestock raising is the main livelihood activity in this region, due to the fact that rainfall is insufficient for some of the major crops (CBS, 2004).

Results from weather station data for the period 1976–2005 indicate high rainfall variability across regions: whereas the Western Development regions have experienced a decrease

Figure 10. Rainfall climatology in Nepal: average annual precipitation in the period of 1984-2007.
(Sources: APHRODITE rainfall product, 2007; DHM, 2010)

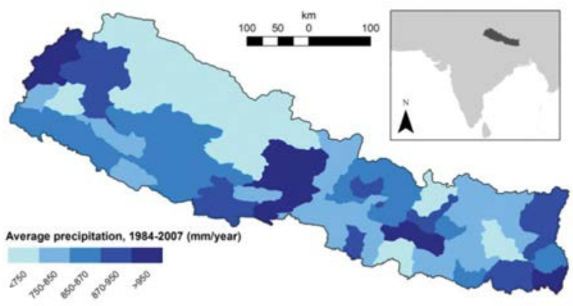


Figure 11. Precipitation trends in different regions of Nepal, 1976–2005.
(Source: Practical Action, 2009)

	Development Regions					
	Mid- and Far Western			Western, Central and Eastern		
	Terai 	Hills 	Mountains 	Terai 	Hills 	Mountains 
Monsoon	Decrease	Decrease	No change	Increase	No change	No change
Post-monsoon	Decrease	Decrease	Decrease	Increase	Increase	Decrease
Annual	Decrease	Decrease	Decrease	Increase	Increase	Decrease

Community perceptions of disaster risk

Across the Terai region, farmers have reported that flooding events are becoming more frequent and more destructive. In addition, diseases and insect infestations are becoming increasingly common, with adverse impacts on the population.

Source: ISET-Nepal (2009)

in precipitation (approximately 10–20 mm/year), the Central and Eastern regions have experienced an increase in precipitation of approximately 10–20 mm/year (also figure 11).

Despite high inter-annual variability, weather station data indicate a decrease in winter precipitation, and an intensification of summer precipitation, leading to more droughts in the winter months and more floods during the monsoon season (Practical Action, 2009).

Disaster trends and impacts

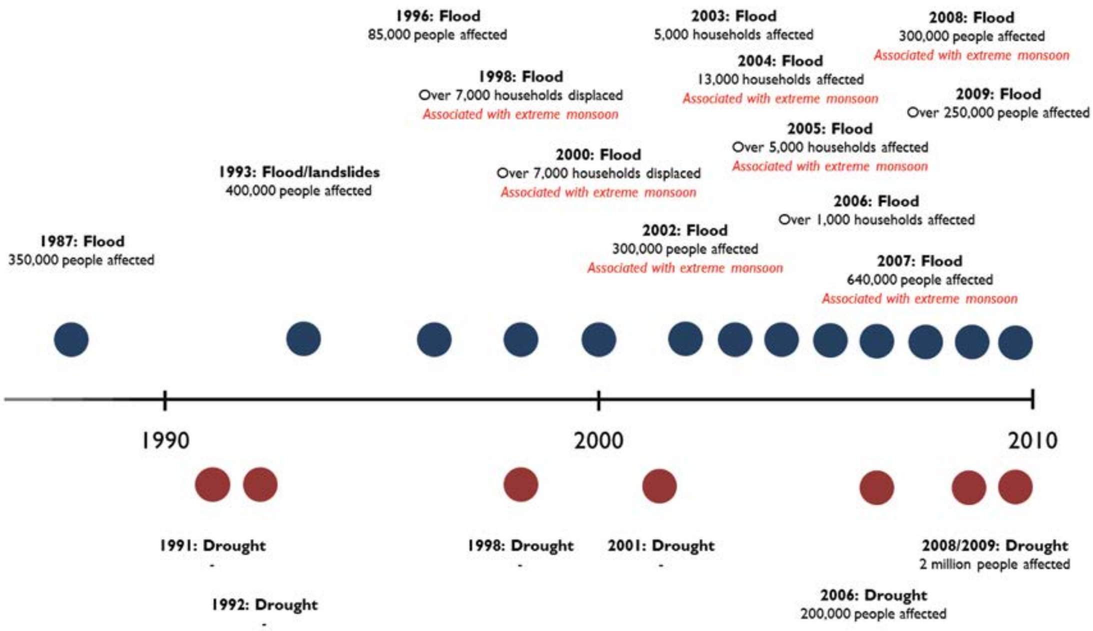
Disaster reports released by ReliefWeb—a service provided by the Office for the Coordination of Humanitarian Affairs (OCHA)—suggest that, over the last 25 years, the impacts of floods occurring during the monsoon months (normally June to August) have increased (figure 12). Between 2002 and 2009, at least one flood with significant impacts on livelihoods and food security has been reported annually. Moreover, since 1998, the majority of these have been linked to extreme monsoons, which could be potentially linked to climatic variability (Fan et al., 2010; Auffhammer et al., 2012).

Increasingly erratic rainfall has been linked to flood risk. For instance, in 2007, floods and landslides caused by torrential monsoon rains affected several districts of Nepal, particularly in the Terai districts of Banke, Bardiya, Dhanusa, Siraha, and Saptari (photograph 1).

Historical weather records suggest no discernible trend in drought frequency (figure 12). However, the winter drought of 2008/2009 was one of the worst on record and affected over 2 million people (Ministry of Agriculture and Cooperatives (MoAC) et al., 2009; photograph 2). As a result of the drought, over 40 districts were food-deficient, in terms of obtaining sufficient food through domestic production, compared to 30 districts in previous years. This type of intense drought is part of a perceived trend of longer and dryer winters (MoE, 2010). At the community level, vulnerable groups in the mountain areas of Nepal have reported a decrease in post-monsoon rainfall leading to negative impacts on crop production (particularly barley, wheat, and potato) and their incomes (Gurung et al., 2010).

Photograph 1. Torrential monsoon rains have been linked to increased flood risk, especially in the Terai region. (Credit: WFP/James Giambrone)

Figure 12. Flood and drought frequency 1987-2010.
(Sources: ReliefWeb, the Nepal Red Cross Society and WFP)



The diagram above shows the frequency of floods and droughts as well as the number of people affected, reported by OCHA's ReliefWeb, the Nepal Red Cross Society and WFP. The diagram also highlights those floods associated with anomalous monsoons. The data suggest an increasing frequency of both floods and droughts, with floods occurring every year since 2002. The available data do not capture the intensity or duration of particular disasters, which are needed to identify trends in magnitude.

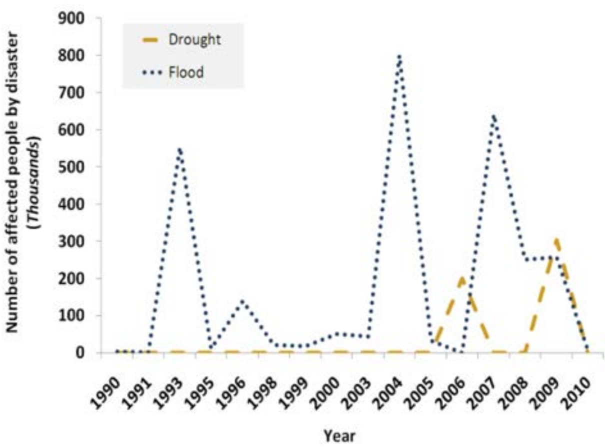
Photograph 2. The 2008/2009 drought was one of the worst on record, affecting over 2 million people. (Credit: WFP/James Giambrone)

The observational record indicates no clear trend in the number of people affected by climate-related disasters. However, there have been years during which larger numbers of people have been affected by disasters in recent years (2004, 2008; figure 13). The incidence of flood, landslide and drought impacts follow a geographical pattern:

- The majority of people affected by floods live in the central and eastern Terai.
- The majority of people affected by landslides live in the central hills.
- The majority of people affected by droughts live in the Mid- and Far Western Development Regions.

No discernible trend in the number of people affected by climate-related disasters can be inferred from the observational record. Recent floods in 2004 and 2008, as well as the droughts of 2006 and 2009 affected several thousands of people, especially in the central and eastern Terai (floods) and mid- and far-western hills and mountains (drought).

Figure 13. Number of people affected by climate-related disasters, 1990–2010.
(Sources: The International Disaster Database (EM-DAT), 2012 (www.emdat.be), DesInventar, 2012)



Projected climate change and impacts

Recent climate variability has affected livelihoods and food security in Nepal. Data reveal that over the last decade around 30 845 hectares of land owned by almost 5% of households became uncultivable due to climate-related hazards—the central part of the country has been the most affected (CBS, 2004). In the eastern Terai, for example, the unusually low rains of 2005/2006 associated with the early monsoon resulted in crop losses of 30% (Regmi, 2007); the cold wave of 1997/1998 also had negative impacts on agricultural productivity resulting in losses of up to 38% for chickpea and lentils, and 28% for potato (Nepal Agricultural Research Council (NARC) 1998).

In addition, recent declines in rainfall from November to April have affected winter and early spring crops. In particular, wheat and barley are highly sensitive to winter precipitation—under lower rainfall variability declines in wheat and barley yields in the western parts of Nepal could exacerbate poverty and food insecurity (UK Department for International Development (DFID), 2009).

Vulnerable populations have also reported significant impacts on agriculture (Gurung et al., 2010). In the mountain regions, some communities in the high-altitude areas have reported positive impacts as a result of the increase in the growing season of some crops. However, winter crops have been adversely affected by reduced snowfall. In the hills, the lack of sufficient precipitation is affecting paddy rice and wheat production. Communities in the Salyan District have diversified to less preferred crops due to the lack of precipitation, while in the Kaski District, wheat yields have declined (Gurung et al., 2010). In the Terai region, communities have reported higher rice yields associated with more intense monsoon rains, when the downpours arrive on time.

General circulation models (GCMs) and regional circulation models (RCMs) both indicate an increase in temperature across Nepal due increases in atmospheric greenhouse gas concentration. According to the global models, temperatures in Nepal are expected to increase by 1.2 °C by 2030 (+/− 0.3 °C) compared to the 2000 baseline, while regional models project a temperature increase of 1.4 °C (+/− 0.5 °C) in the same period. In general, models agree that higher temperature increments are expected in the winter season, especially in the Far Western Development Region (Intergovernmental Panel on Climate Change (IPCC), 2007; MoE, 2010).

Precipitation projections show no clear trends across the country, but generally models suggest minor or no decreases in precipitation patterns in western Nepal, and increases of up to 10% annual rainfall in eastern Nepal. The majority of this increase is due to more intense monsoon precipitation, resulting in up to a 20% increase in rainfall in the summer months; such an increase in rainfall could lead to more frequent and intense floods in the central and eastern Terai. Overall, models also suggest a decrease in post-monsoon rainfall in the winter months in the western regions of the country, potentially leading to droughts of higher magnitude in the mid- and far western hills and mountains. Moreover, reduced winter precipitation adversely affects communities in the mountain and hill regions whose populations depend on livestock and winter crops. Overall, the precipitation projections correspond to observed historical trends (IPCC, 2007; Practical Action, 2009; MoE, 2010).

In addition, Nepal is vulnerable to the impacts of glacial lake outburst floods (GLOFs). While glacier melt provides water for agriculture and the raising of livestock in the mountain and hill regions, accelerated melt could lead to negative impacts on food security and livelihoods. What's more, although other climate-related disasters such as rainfall inundations, landslides and droughts have had a significant impact on livelihoods and food security, GLOFs have great potential for devastation in a single event (Kattelmann, 2003; International Centre for Integrated Mountain Development (ICIMOD), 2011).

With moderate rising temperatures in the mountain areas of Nepal in recent years, several glaciers have melted rapidly resulting in glacial lakes. On average, air temperatures in the Himalayan regions have increased by 2.1 °C since the 1970s. Out of 3 252 glaciers and 2 323 glacial lakes in Nepal, 20 are considered to be potentially dangerous and 6 are considered to be critically dangerous. One such lake is the Tsho Rolpa, fed by the Tradkarding glacier, which is retreating at a rate of 20 metres a year (United Nations Environment Programme (UNEP), 2002). Due to melting of the glacier, the lake has grown six-fold (from an area of 0.23 km^2 in the late 1950s to 1.5 km^2 at present). This development poses a high risk to people downstream in the village of Triveni—as 30 m^3 of water are released, about 10 000 lives, thousands of livestock, agricultural land and critical infrastructure could be affected (Rana et al., 2000). The destruction could result in costs of up to USD 22 million (Richardson, 2004).

Regional climate

It is impossible to understand the whole range of climate impacts on food security by excluding regional climate trends. Although regional climate is particularly difficult to generalize due to the complex topography of the region, evidence suggests that climate and food security trends in other South Asian countries also affect Nepal—for instance, lower production in India, associated with low precipitation, has sometimes been linked to higher food prices in Nepal due to dependence on imports from India[2] (WFP, 2010). This is because rainfed agriculture, which is common across most of South Asia, relies on monsoon rainfall. Therefore, years with anomalous monsoons (either extremely low or extremely high precipitation) are associated with food security crises in the region (figure 12).

Acknowledging these relationships, this analysis highlights potential linkages between climate and food security at the regional level where possible[3].

2. The same monsoon outcome would affect crop production in Nepal as well.
3. A regional analysis of climate trends was not carried out, as the objective of this analysis is to identify relationships between climate variability and food security at the national level, to identify nationally relevant adaptation strategies.

Climate and food security

Climate and crop production

The distribution of rainfall over the year and over the country generally follows one of three patterns:

1. The main rainy season (monsoon) occurs from June to September. Approximately 80% of the annual rainfall occurs during this period, and covers most of the country excluding the northern Himalayan region. The Mid- and Far-Western Development Regions get less rain than the Western, Central, and Eastern Development Regions.
2. Westerly winds bring occasional rain in winter and early spring to the Mid- and Far-Western Development Regions.
3. During the pre-monsoon months (March to May), local rains may occur over the hills and Terai—largely as thundershowers. These relatively unpredictable rains affect the agricultural cycle when they result in floods or landslides.

Based on this distribution of rainfall, the majority of crops—including paddy, maize, millet, and potato—are grown between May and August to benefit from the monsoon rains, particularly in hill and Terai regions. In the Mid- and Far-Western Development Regions, the primary crops (wheat and barley) are grown between December and February when the winter rains occur.

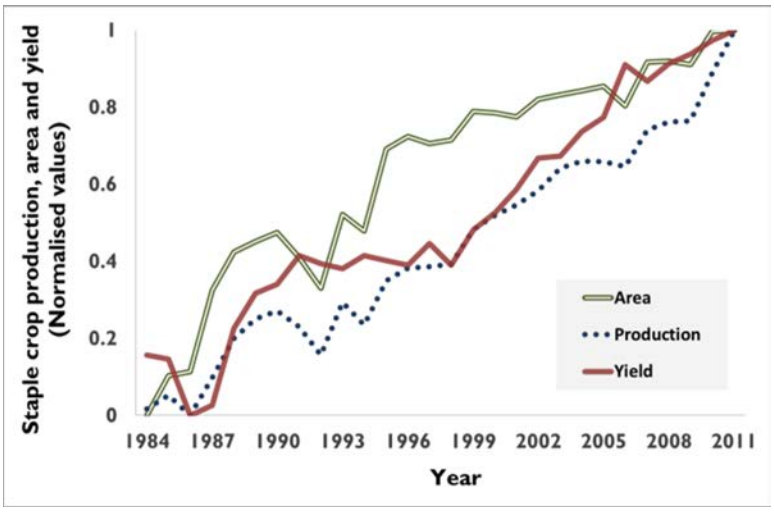
Crop production trends

Agricultural production, yield and the area harvested for the 6 most common crops in Nepal (paddy rice, maize, millet, wheat, barley and potato) increased steadily since 1984.

This increase in production occurred up to the 1990s, largely due to area expansion rather than increases in yields—this is particularly true in the case of maize and wheat (Paudyal, 2001; NARC, 2007; figure 14).

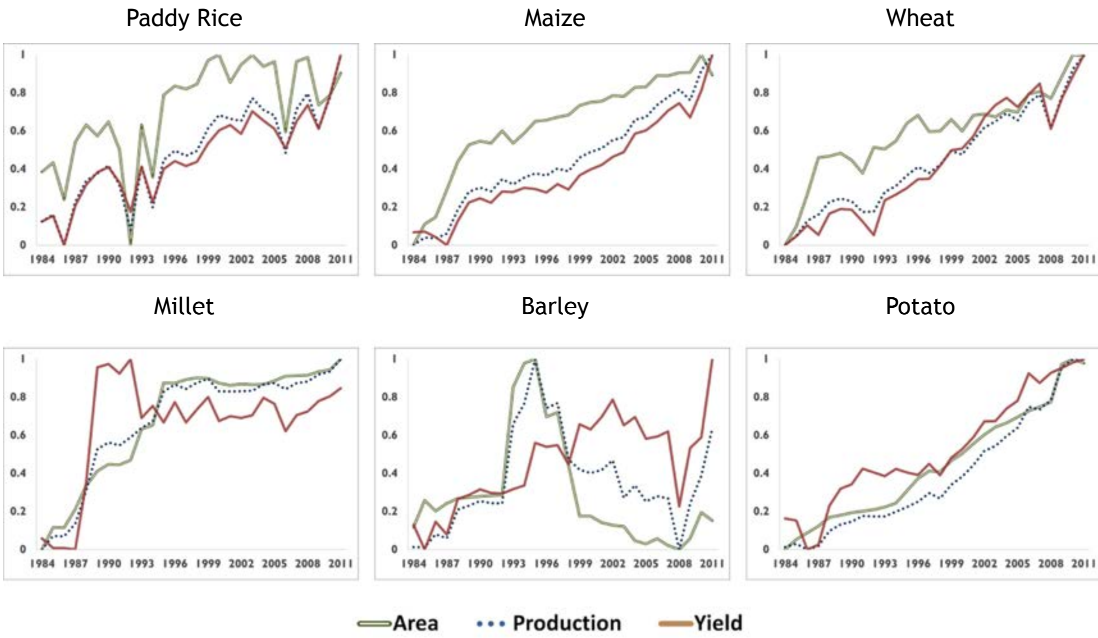
In the period 1996–2008, however, productivity increased more rapidly than the area under cultivation. Today, production trends for the main crops in Nepal continue to show a relatively stable increase in area cultivated, production and yields, with the exception of barley and millet. Millet yields have been relatively stable after reaching a peak in 1999, with the

Figure 14. Crop trends in Nepal, 1984–2011.
(Source: MoAC, 2010)



amounts of cultivated area and production largely unchanged. In contrast, barley production has been decreasing consistently since 1996 due to a combination of two factors. On the one hand, a number of recurring winter droughts in key production areas have forced farmers to identify alternative crops (Regmi, 2007). On the other, barley is considered a minor crop, so farmers diversified into other crops as soon as alternatives become viable (WFP and NDRI, 2010).

Figure 15. Normalized trends of cultivated area (hollow green), production (dotted blue), and yield (brown) of (a) paddy rice, (b) maize, (c) wheat, (d) millet, (e) barley, and (f) potato, 1984-2011.
(Source: MoAC, 2010)



Climate-yield relationship

Quantifying the relationship between crop yields and climate is difficult. Given the importance of non-climatic variables including, among others, sub-national differences in farm inputs such as choice of fertilizers, irrigation techniques and seeds, as well as economic changes influencing agricultural management techniques are also very important. The results of this analysis show that yields are particularly sensitive to precipitation—particularly rice and wheat. Therefore, in the absence of adaptation measures, changes in precipitation patterns due to climate change could have a significant adverse impact on food production in the country.

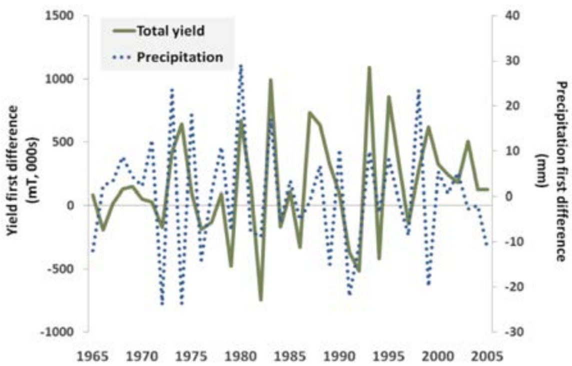
Precipitation

A further examination of inter-annual and longer-term climate variability during the last four decades reveals the relationship between climate and agricultural production in Nepal, as illustrated by the correlation between precipitation anomalies and staple crop yields (figure 16). Using year-to-year differences in time for climate and crop production (that is, the difference in values from one year to the next), the relationship between both indicators can be evaluated, assuming that trends are attributable to technological advances (cf. Lobell and Field, 2007).

Photograph 3. Communities in the mountain district of Humla (Far-Western Development Region) have reported that erratic rainfall patterns in the rainy season have affected their crop production. (Credit: WFP/James Giambrone)

Differences in precipitation have a larger explanatory power than temperature in relation to food production. There is a positive correlation (R=0.478, p<0.05) between precipitation and overall yields for paddy rice, maize, millet, wheat and barley. Rice (R=0.504, p<0.05) has the largest correlation. This is explained by the fact that rice has high water requirements and is highly sensitive to drought, while millet has low water requirements and is less sensitive to drought (Brouwer and Heibloem, 1986). While higher precipitation can be generally associated with higher yields, it is important to note that extreme rainfall could lead to flood events and consequently to lower crop production.

Figure 16. Precipitation and yield correlations, 1975–2005.
(Source: MoAC, 2010; DHM, 2011)



Crop	Pearson's coefficient
Cereals	**0.478**
Paddy	**0.504**
Maize	0.158
Millet	−0.002
Wheat	**0.360**
Barley	0.030
Potatoes	0.149

Statistically significant values are shown in **bold**.

The correlation is particularly strong (R = 0.686, p<0.05) in the earlier part of the observational record (1965–1995) during which slight increases in rainfall were associated with higher yields. In recent years, however, the correlation between precipitation and yields has been weaker. This suggests that communities might have already started to adapt to rainfall variability through water management, irrigation technologies and crop diversification (Gurung et al., 2010).

Seasonal variability

To further examine the relationship between crop production and precipitation, the correlations between production and average seasonal precipitation during the main growing season were evaluated (cf. Joshi et al., 2011).

The explanatory power of seasonal precipitation is higher for winter crops (close to 50%) than for summer crops (close to 30%) as shown in Table 1. These results indicate that winter crop yields are highly dependent on post-monsoon rains. In recent years, changes in the monsoon behaviour associated with El Niño cycles have resulted in lower winter precipitation (or none at all in some years) (Shrestha et al., 2000), which have affected wheat and barley production. The lower correlation between summer precipitation and summer crop yields is explained by the high inter-annual variability in monsoon rain. Moreover, summer crops (paddy to a lesser extent) can be affected by extreme precipitation and flood events, which are more likely to occur in the summer. An alternative explanation is that most of the rainfall occurs in the monsoon period, and therefore variability in precipitation would have little impact on yields provided the monsoon arrives on time. However, rainfall is limited in the winter and therefore winter crops are highly sensitive to small changes in rainfall patterns.

Table 1. Correlation between crops and growing season precipitation.
(Source: Calculations based on data from MoAC, 2010; DHM, 2011)

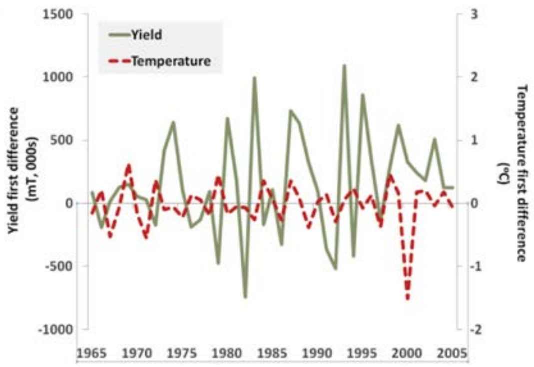
Crop	Correlation
Wheat (winter crop)	**0.533**
Barley (winter crop)	**0.495**
Paddy (summer crop)	**0.460**
Maize (summer crop)	**0.357**
Millet (summer crop)	0.349
Summer potatoes (summer crop)	0.292

Statistically significant values are shown in **bold**.

Temperature

Variability in temperature has a lower explanatory value with respect to yields than precipitation (R=−0.097, p=0.151; figure 17). The temperature sensitivities are positive for millet, wheat, barley and potatoes, suggesting that these crops are more heat-resistant than paddy rice or maize (cf. van Oosterom et al., 1995; Crafts-Brandner and Salvucci, 2002; Barnabas et al., 2007).

Figure 17. Temperature and yield correlations, 1975-2005.
(Source: Calculations based on data from MoAC, 2010; DHM, 2011)



Crop	Pearson's coefficient
All cereals	−0.172
Paddy	−0.149
Maize	0.246
Millet	0.104
Wheat	0.062
Barley	0.064
Potatoes	0.009

No statistically significant results.

Seasonal variability

The relationship between crop production and seasonal temperature trends was also evaluated (cf. Joshi et al., 2011). The explanatory power of seasonal mean temperature is lower, compared to precipitation and is similar across both winter and summer crops (10–20% of the variability in yields is explained by temperature trends). Almost all crops have negative correlations with temperature, except for maize and millet—both of which are more heat tolerant (Joshi et al., 2011). The results suggest that, overall, an increase in temperature in key production areas could result in yield losses of paddy, potatoes, wheat and barley, although maize and millet yields may benefit from an increase in temperature. This is especially the case in the hill and mountain areas where particularly high observed warming rates could affect production of maize and potato—the two main staples produced in these regions.

Table 1. Correlation between crops and growing season temperature.
(Source: Calculations based on data from MoAC, 2010; DHM, 2011)

Crop	Correlation
Wheat (winter crop)	**−0.153**
Barley (winter crop)	**−0.177**
Paddy (summer crop)	−0.181
Maize (summer crop)	**0.105**
Millet (summer crop)	**0.149**
Potatoes (summer crop)	−0.189

Statistically significant values are shown in **bold**.

Price trend

Establishing a correlation between food prices and climate variables is difficult in the context of Nepal. Given that food prices are significantly affected by prices in India, it is likely that potential results are influenced by the climate-price relationship in India.

For this analysis, average monthly retail prices from 21 markets were considered[4]. A correlation analysis suggests that the variability of food commodity prices is more closely correlated with climate variables for maize and rice, compared to wheat and pulses (table 3). The explanatory power of this model is largely explained by a correlation with precipitation trends.

Table 3. Summary statistics of regression models. (Δprice = Δtemperature + Δprecipitation), 1985–2005.
(Source: Calculations based on data from MoAC, Department of Agriculture, Agribusiness Promotion and Marketing Development Directorate, 2012; DHM, 2011)

Crop	Model R^2
Wheat	0.151
Rice	0.148
Lentils	0.060
Maize	0.010

4. The markets considered for this analysis are: Achham, Banke, Bhojpur, Chitwan, Dhankuta, Dhanusha, Doti, Ilam, Jhapa, Jumla, Kailali, Kaski, Kathmandu, Morang, Nuwakot, Palpa, Parsa, Ramechhap, Rolpa, Rupandehi and Surkhet.

Climate-price relationship

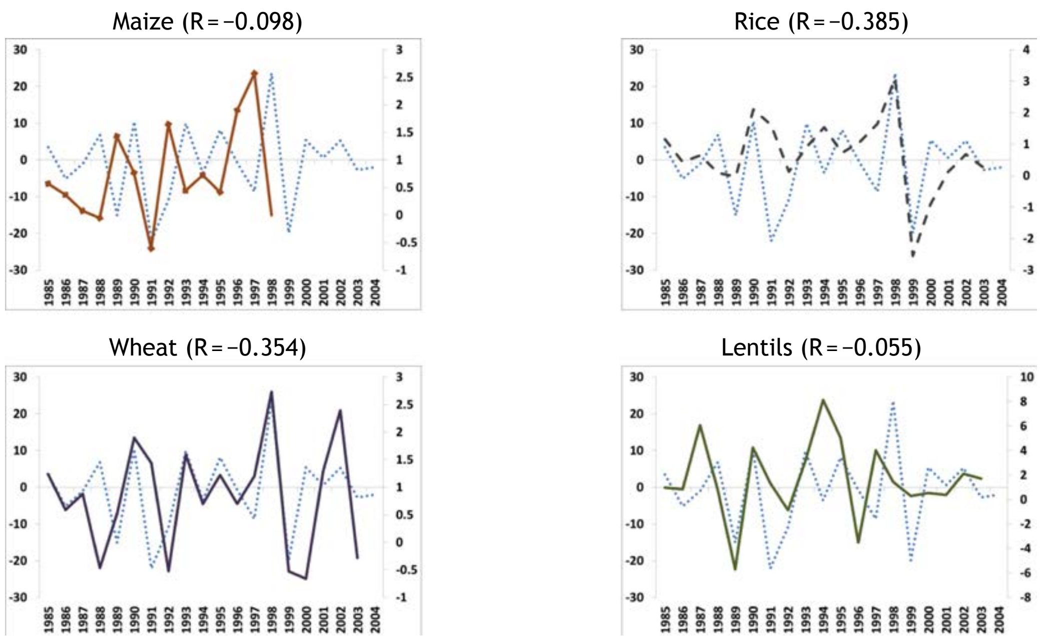
Food commodity prices for rice, maize, wheat and pulses were examined in relation to precipitation and temperature. The results indicate that food prices are generally negatively correlated with precipitation and positively correlated with temperature. Establishing relationships between climate variables and food prices is challenging because food prices are influenced by a number of factors, including fuel prices in-country and food prices in other countries.

The relatively low correlations between climate variables and food commodity prices, compared to yields, corroborate the findings of previous studies, which suggest that socioeconomic development paths are more important for food access than climate parameters (Schmidhuber and Tubiello, 2007). In particular, national food commodity prices in Nepal are influenced by prices in India, so attributing climatic factors alone to changes in food prices is premature.

Precipitation-price correlation

All food prices are negatively correlated with precipitation in the period 1985–2005, suggesting that food prices have been generally higher in drought years (WFP and NDRI, 2010; Figure 18). Rice prices have the highest negative sensitivities in relation to precipitation and prices are highly correlated with production—these results corroborate the high water requirements of this crop. Lentil prices have the lowest correlation with precipitation suggesting that the price elasticity of pulses is largely determined by other non-climatic factors.

Figure 18. First-difference trends in precipitation (dotted blue; right axis) and maize, rice, wheat and pulse prices (NPR/kg; left axis), 1985-2005. Correlations are shown in brackets.
(Source: Calculations based on data from MoAC, Department of Agriculture, Agribusiness Promotion and Marketing Development Directorate, 2012; DHM, 2011)



Temperature-price correlation

Food prices are positively correlated with non-detrended temperature (figure 19). These results indicate that food prices are highest in warmer years, corroborating the findings of previous studies (cf. Thorton et al., 2011). While it is difficult to ascertain how significant this difference is, the results suggest that super-optimal temperature in the growing season could have detrimental impacts on food prices if key production areas are affected, especially at the global level (Nelson et al., 2009; 2010). In the context of Nepal, changes in imports from India could affect food prices.

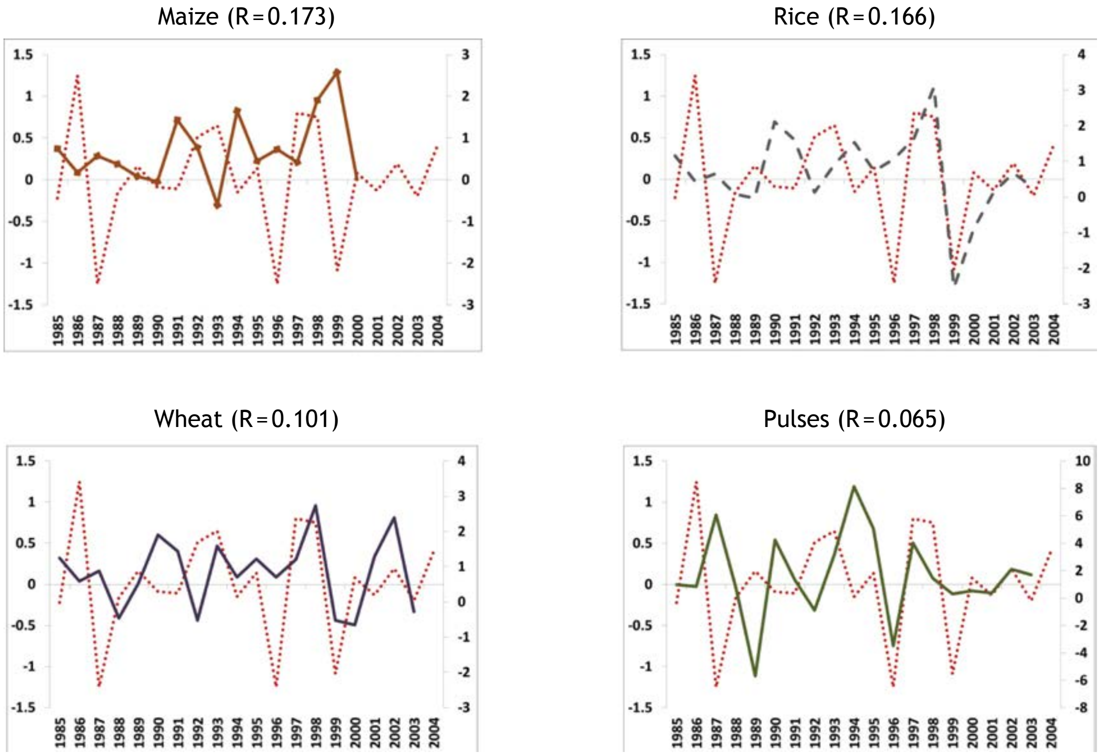
Global analyses have identified relationships between climate trends and food prices (for example, Fischer et al., 2002), and climate-related events and food prices (Battisti and Naylor, 2009). However, the forgoing analysis highlights that it is difficult to evaluate the relationship between climate trends and food prices in individual countries—in the context of Nepal, particularly, this is due to the fact that the market mechanism determining food prices is far from perfect and prices are also influenced by prices in India and significant transport costs (WFP, 2010).

Climate impacts on livestock products

Climate variability could also have an impact on livelihood activities and, consequently, on incomes. Livestock rearing and livestock product sales contribute to income sources, particularly in the mountain and hill regions. Therefore, if climate variability affects livestock production, rural livelihoods would be affected.

Figure 19. Trends in temperature (dotted red; right axis) and maize, rice, wheat and pulse prices (NPR/kg; left axis), 1969–2000. Correlations are shown in brackets.

(Source: Calculations based on data from MoAC, Department of Agriculture, Agribusiness Promotion and Marketing Development Directorate, 2012; DHM, 2011)



Livestock products have a strong correlation with climate variables (figure 20). In particular, precipitation trends explain over 30% of inter-annual variability in the production of wool ($R=0.463$, $p<0.05$), milk ($R=0.392$, $p<0.05$) and eggs ($R=0.338$, $p<0.05$). The results imply that wool production is particularly sensitive to rainfall: the largest decline in wool production occurred in 1992 and occurred simultaneously to a large decline in precipitation which was, in turn, driven by a multi-year El Niño Southern Oscillation event (Shrestha et al., 2000).

Figure 20. First-difference trends in precipitation (blue; right axis) and milk, meat, eggs and wool (dotted lines, left axis), 1985–2003-correlations shown in brackets.

(Source: Calculations based on data from MoAC, 2010; and DHM, 2011)

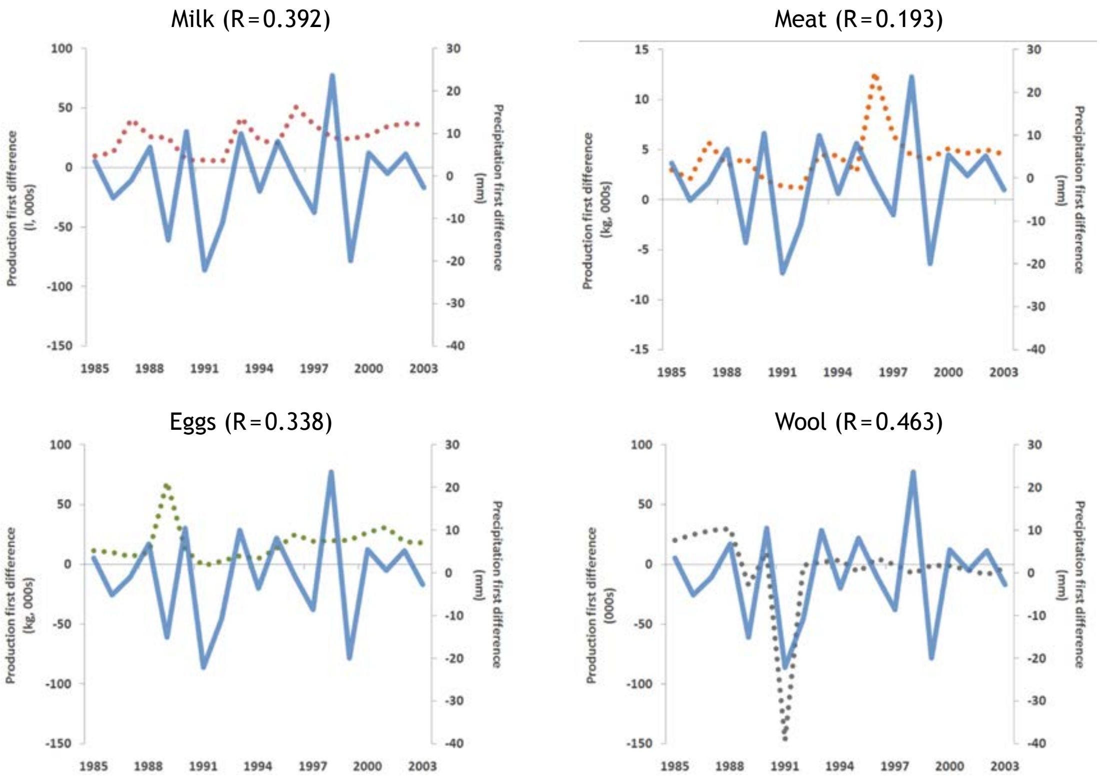


Table 4. Correlations between livestock products and temperature (1985–2003).

Product	Pearson's *R*	p-value
Milk	0.074	0.215
Meat	0.010	0.432
Eggs	−0.207	0.081
Wool	−0.135	<0.05

The statistical relationship between temperature and livestock products is less clear. Eggs and wool production respond negatively to increases in temperature, corroborating other studies that identify correlations between increases in temperature and lower wool (Harle et al., 2007), and egg production (Visser et al., 2006) in other geographic contexts. The correlations between temperature and milk, and temperature and meat are statistically insignificant suggesting that temperature might only have a marginal impact on these in Nepal (table 4).

The following discussion highlights that significant changes in precipitation patterns, particularly in the mountain and hill regions, could have a detrimental impact on livestock production. This, in turn, could result in loss of income and purchasing power.

While climate trends might have had an impact on wool (for example, through the reduced availability of grazing land), the sudden decline in wool production between 1990 and 1991 suggests that other social factors should also be taken into account. The anomalous drought might have had two outcomes: firstly, it could have reduced the amount of grazing land available (therefore the productivity of sheep), and secondly it might have encouraged the population of the mountain regions to migrate as an adaptation strategy. Moreover, livestock epidemics in the 1990s could have reduced the incentives to farm livestock, and more specifically sheep, in the mountain regions—indeed, the number of sheep declined in 1989/1990 (FAO, 2005). In addition, the livestock situation in a number of districts in northern Nepal also depends on access to pastures in the adjoining areas of Tibet in the People's Republic of China. The decline in wool production could have also been a response to lower market demand for wool. Therefore, while climate appears to have an impact on wool and other livestock products, other factors are likely to have influenced the decline in wool production.

Migration as a coping strategy

Migration is an important coping strategy for at-risk populations, especially in the mid- and far-western hills and mountains of Nepal. Seasonal migration, within and outside of the country, in search of income opportunities has been a common coping strategy for rural communities (WFP and NDRI, 2009). Migration can be ex-ante, in anticipation of a shock, or ex-post, in response to a shock. Under climate change, the frequency, intensity and duration of certain shocks (particularly droughts and floods) could exacerbate out-migration. Adaptation strategies should focus on providing support to migrants and receiving communities.

Migration is a common strategy, especially among the poorest households, and it is used by around 25% of the adult male population. Migration is often employed as a coping strategy by households that have experienced a shock—in particular, lack of access to food and employment are by far the most common reasons for migration.

Santosh Nepali, a 29 year-old male from Kudari VDC in Jumla, explains that migration was the only solution because "[T]here were many problems at home. There were three consecutive years of drought. Then a bullock died. I also got married. We had to buy food, which is expensive. My parents became sick and the cost of medicines was very high. We were poor, so every time one of these problems came our way, we had to take out a loan to pay for it. We had debts of 35 000 Nepalese Rupees (NPR)." This example illustrates the importance of migration as a coping strategy.

While remittances offer a significant benefit, the poorest migrants obtain only marginal benefits—for the poorest people, the main benefit is a reduced burden on family food stocks, rather than additional income from remittances. After accounting for travel costs and interests, the average financial benefit for the very poor migrants is NPR 4 350–5 210. To support the most vulnerable communities, it would be important to prioritise strategies that support income-generating activities among the poorest households to account for the income they would obtain from migration, while also aiming to enhance environment and adaptation options.

Sources: WFP and NDRI (2009)

Food security and livelihood sensitivities to climate

This section analyses the sensitivity of households in Nepal to climate risk using data from the Nepal Living Standards Survey 2010/2011 (NLSS-III). This was done by considering how different livelihood components, such as income diversification, food sources, markets and wealth groups relate to food security and coping strategies, and how these might be affected by climate trends. The analysis is done by analytical domain, as recommended by the CBS in Nepal[5].

Food security situation

The main indicators of food security are calorie intake, quality of diet, food consumption and the seasonality of food consumption.

There is no single measure of food security. Indicators for quantity of diet (caloric intake), quality of diet (diversity) and the adequacy of food consumption all provide useful information about food security trends and problems across the country. For example, while some regions might have access to sufficient energy for a healthy lifestyle (rich diet quantity), all the calories might come from one single food source (poor diet diversity). Similarly, the food security situation in some regions of Nepal varies throughout the year, with food security being particularly low in the agricultural lean seasons. It is therefore important to consider multiple indicators of food security to obtain a more accurate picture of overall food security.

Diet quantity

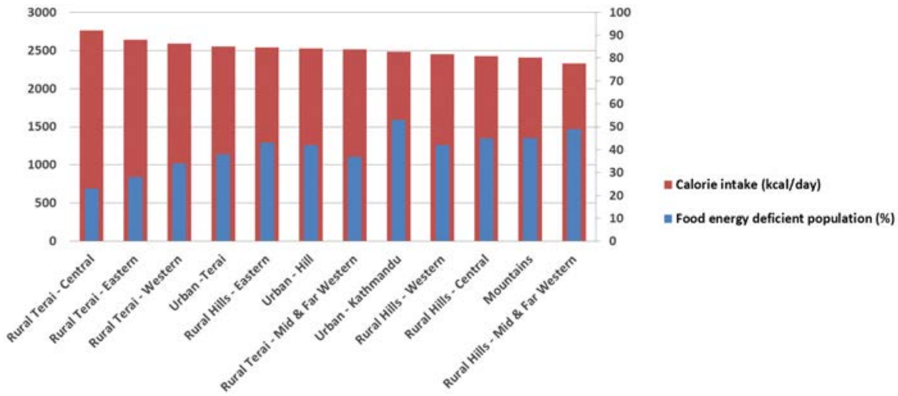
According to the NLSS-III, the national average kilocalorie (kcal) intake is 2 536 kcal per capita per day—higher than the average adequate requirement of 2 220 kcal set by the Government of Nepal. In urban areas, 43% of the population consumes less than the minimum caloric threshold compared to 37% in rural areas. However, when interpreting this result it is important to consider that the energy demands for a healthy active life in rural areas typically exceed those in urban areas due to increased activity. In addition, calorie intake may not have been accurately captured in urban areas due to the frequent consumption of meals away from home. Food energy intake varies significantly between Nepal's geographic regions. The greatest per capita intake of calories is in the central rural Terai (2 762 kcal per day) compared to the lowest per capita intake in the rural mid- and far-western hills (2 330 kcal per day) (Figure 21).

Diet quality

Poor diet quality, measured by diversity of food sources, is a serious problem across much of Nepal. While the average Nepalese person consumes enough calories to live a healthy, active life, staple food items constitute 72% of the average household diet. For this analysis, households that consume more than 60% of their total calories from staples are considered to have a 'high' staple diet, and households that consume more than 75% of their total calories from staples to have a 'very high' staple diet (NPC and CBS, 2013). More than 84% of households in rural areas have a 'high' staple diet and more than half (52%) have a 'very high' staple diet. Almost 70% of the urban population has a 'high' staple diet, however only 19% of the urban population has a 'very high' staple diet, highlighting the critical importance of staples in rural areas.

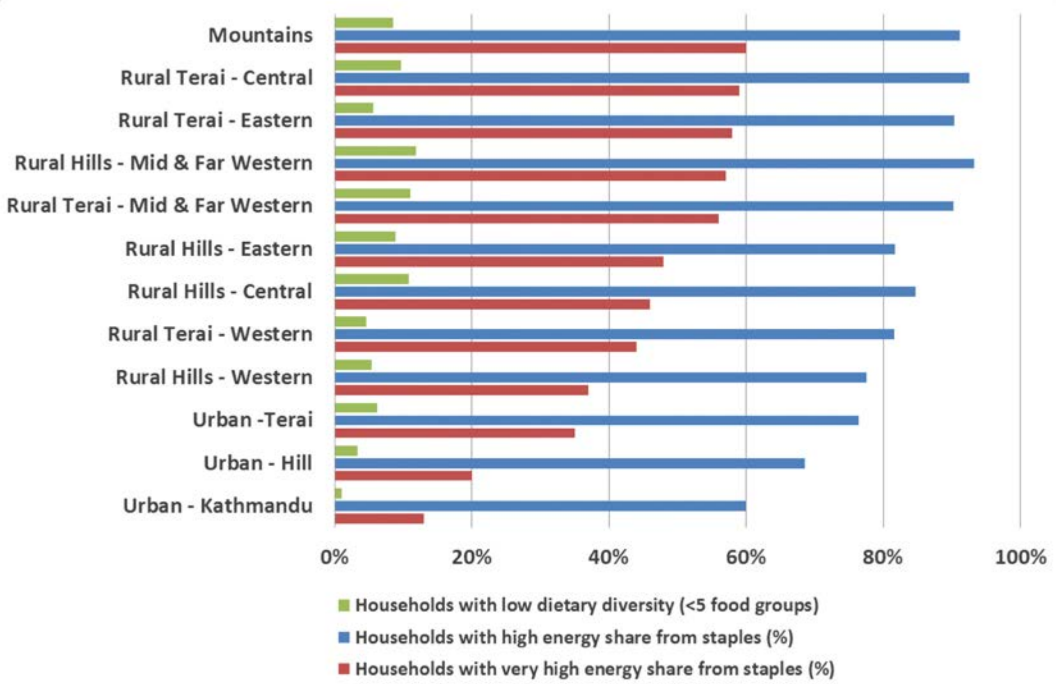
5. Twelve analytical domains are used for this analysis: mountains, rural hills; eastern rural hills; central rural hills; western rural hills; mid- and far-western rural Terai; eastern rural Terai; central rural Terai; western rural Terai; mid- and far-western urban; Kathmandu valley, urban; hills, urban; Terai. Each of these analytical domains contains approximately 30–35 clusters of households, located in different districts, allowing for a generalization of food security in the area. Some districts belong to two analytical domains so it is not possible to map the livelihood and food security indicators accurately.

Figure 21. Diet quantity by region—calorie intake and proportion of population consuming less than the minimum caloric threshold.
(Source: CBS, 2011)



Households that have consumed food from 4 or less food groups (out of 8) within a 7-day reporting period are considered as having 'low' diet diversity (NPC and CBS, 2013)[6]. In 2010/11, this accounted for 8% of Nepalese households, representing 4% of the urban population and 9% of the rural areas. Populations in some regions of Nepal are particularly prone to poor dietary diversity. The reasons for this relate to issues of availability and access. In mountain areas, 60% of the population have a 'very high' staple diet and over 10% of the population in varying hill and Terai regions consumed less than 4 food groups within the reporting period, highlighting the poor diet quality in the mountains and some rural hill and Terai regions (figure 22).

Figure 22. Diet quality by region: proportion of households with: (i) low diet diversity (top, green); high staple diet (middle, blue) and very high staple diet (bottom, red).
(Source: CBS, 2011)



6 Often dietary diversity is measured using 24-hour recall instead of a 7-day period.

Adequacy of food consumption

Adequacy of food consumption can be determined through the food consumption score (FCS)[7], which assesses the frequency of consumption of various food groups within the reporting period (7 days) and through food poverty, which measures the proportion of people who consume a diet with a value below the cost of a basic adequate diet. The basic diet is based on the average diet makeup of poor households, such that the diet provides sufficient kilocalories (based on the threshold set by the Government), and the cost is determined by local food prices. Both techniques include measures of diet quantity and quality—but FCS focuses more heavily on dietary diversity, whereas food poverty focuses on the overall quantity of consumption. These measures are complementary and should be analysed together to identify food security patterns.

Based on the FCS, the average household's food consumption in both rural and urban areas of Nepal is considered to be adequate (above a threshold of 42). However, there is still a relatively high proportion of the population, 19%, that consume an 'inadequate' diet and 7% of the population are considered to consume a 'poor' diet (an FCS below 28). At the national level, 25% of the population are living in food poverty (this is also the percentage of the population considered poor).

The average FCS in urban areas is 74, compared to an average FCS of 60 in rural areas. The likelihood of being either food poor or having an inadequate FCS is more than twice as high in rural areas, where 22% of the population consume an inadequate diet and 28% are considered food poor. This compares to 9% with an inadequate diet in urban areas and 12% food poor.

While the FCS and food poverty measures show relatively consistent differences between rural and urban areas, at a regional level there are some substantial differences in how areas rank under the two measures. Areas that have high rates of both inadequate FCS and food poverty include the mountains, central rural hills, the mid- and far-western hills and Terai (figure 23).

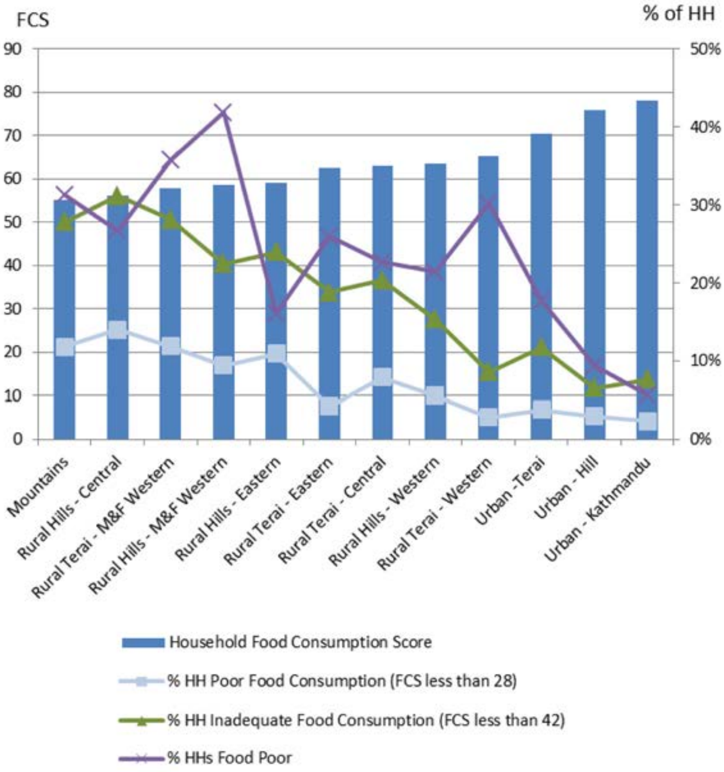
Seasonality of consumption

An analysis of average monthly consumption trends provides a better understanding of seasonal vulnerability to food insecurity. Seasonal vulnerability is important—if households cannot even-out their consumption across the year, it highlights a pattern of chronic food insecurity where households constantly slip in and out of hunger based on their own food production cycles. Seasonal variability is also an indication of when households need assistance the most. By analysing patterns in kilocalorie consumption during 2010/11, it was possible to identify the months in which households were most energy deprived and vulnerable to hunger. An analysis of the sources of food consumed also provided a basic understanding of how households maintained their food consumption during the year through a mix of their own production, market purchases and in-kind food support.

Typically, most regions of Nepal are assumed to have two agricultural lean periods per year: a summer lean period (July to September) and a winter lean period (February to April). A specific analysis was undertaken in this study to determine how food consumption changed during these periods and whether agricultural lean periods were also periods of heightened food insecurity. The seasonal analysis, below, has been categorized by mountains, hills and Terai. There is significant variation across the Development Regions even within these broad

7 The Food Consumption Score is a composite indicator based on dietary diversity, food frequency, and the relative nutritional importance of different food groups. It is considered to be a core indicator of food security and the higher the score, the better the overall diet.

Figure 23. Regional food consumption scores and percentage of households with inadequate consumption.
(Source: CBS, 2011)



ecological belts. For example, food insecurity is more prevalent in Mid- and Far-Western Development Regions compared to other areas in all ecological belts.

Mountains

In mountain regions, the bulk of food consumed comes from household production: in an average household, 53% of the food consumed comes from its own production, 40% from food purchased locally, and 7% from in-kind food support. In 2010/11, the consumption of food grown by households decreased significantly due to agricultural lean periods. For instance, in September 2010, towards the end of the first agricultural lean period of the year, households consumed on average 760 kilocalories per day from their own production, compared to 1 650 kilocalories in October and November following the harvest period. The data suggests that households consumed the bulk of their own production in the months immediately following harvest and then relied on procured food during other periods. Given that market food prices are often highest when the most food was being bought, it would

Community perceptions of the relationship between climate risk and market dependence

In the Village Development Community of Patamara (in Jumla), the relationship between climate risk, food production and dependence on food markets has become increasingly clear. Ujeli Bista, a village leader explains:

"These years there has been no snowfall in this village at all and each year the rain is coming less and less. Our village used to have enough food for an entire year. If there was drought, the village would share. Now, no household has food for more than three months—so the men must migrate to India. With the money, we have to buy rice in Surkhet and carry it back."

Source: WFP (2009)

appear that households were adhering to this pattern of consumption through necessity rather than for economic reasons.

During both lean periods in 2010/11, households supplemented their diets with procured food and in-kind food support. Sufficient cash, access to credit (to purchase food) and in-kind food support are critical for maintaining a diet with adequate kilocalorie consumption. For instance, in April 2010, it can be seen that households did not consume enough produced or purchased food to consume above the minimum average threshold set by the Government of Nepal. As there was no in-kind food consumed by surveyed households, average kilocalorie consumption was inadequate. In contrast, during the lean period in February 2011 it can be seen that, although the consumption of their own production was very low, households were able to maintain adequate kilocalorie consumption by purchasing food and receiving a significant amount of food in-kind. Also, in May 2010, in-kind food support lifted many households above the kilocalorie consumption threshold.

A review of key food security indicators during the two agricultural lean periods shows that consumption was significantly worse during the February to April lean season compared to other times of the year. Across most indicators there was not a significant difference in consumption between the August to September lean period and the rest of the year.

Rural hills

In hill regions, the bulk of food consumed is purchased. In an average household, 40% of the food consumed comes from its own production, 57% from food purchased locally, and 3% from in-kind food support. Compared to households living in mountain areas, rural households in hill areas were generally better able to smooth out the consumption of their own production throughout the year and balance it with the food purchased to even out overall consumption. However, it must be noted that there is both insufficient data to analyse food source trends at the regional level and the potential for significant regional variability. Key consumption indicators generally indicated poorer consumption during lean periods, particularly in relation to the consumption of 'very high' staple diets—43% of households consumed 'very high' staple diets during the first agricultural lean period, and 45% during the second period. This indicates that, although households were able to smooth out their overall kilocalorie consumption during the year, during agricultural lean periods they also had to rely on consuming less nutritious and less expensive foods.

Figure 24. Mountain population, average monthly kilocalorie consumption by source.
(Source: CBS, 2011)

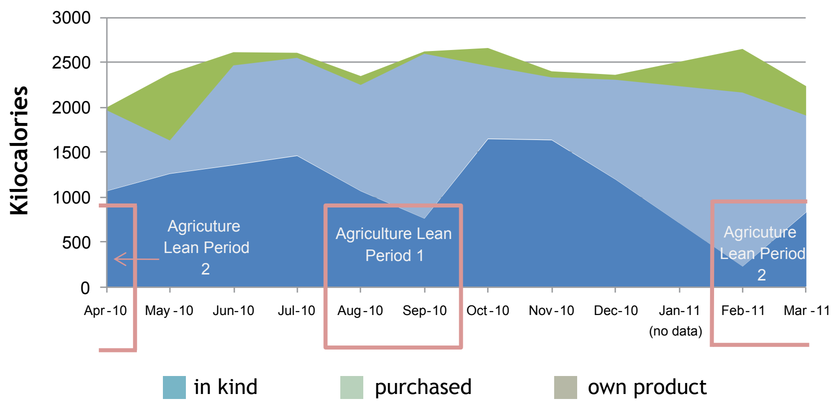
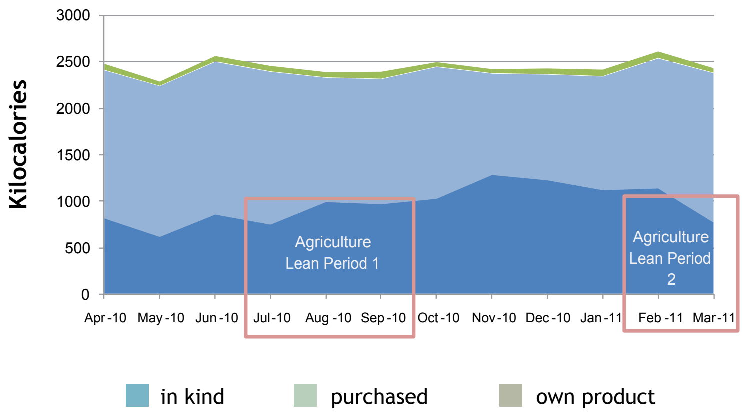


Figure 25. Hill population, average monthly kilocalorie consumption by source.
(Source: CBS, 2011)

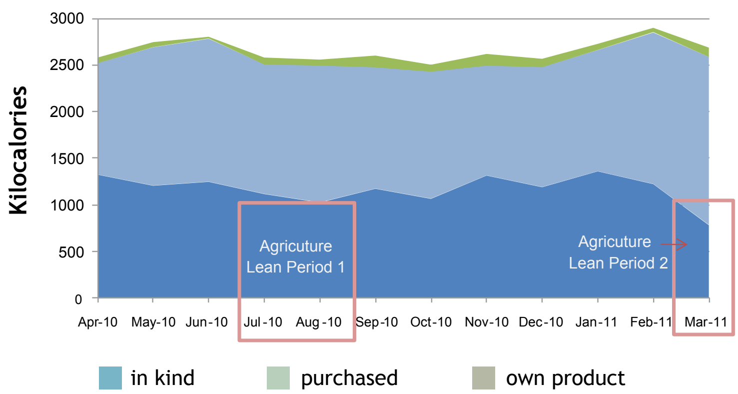


Rural Terai

In the Terai regions, the bulk of food consumed is purchased. In an average household, 43% of the food consumed comes from its own production, 54% from food purchased locally, and 3% from in-kind food support. In 2010/11, the consumption of food produced by households in the Terai was relatively even across the year. The most notable exception was in March—towards the end of the second agricultural lean period—when the percentage of population that was considered to be food deprived increased to 37%. Throughout the year, the average household was able to even out its consumption with purchased food, and when key food security indicators are considered, there were no overall fluctuations in food security correlating to the agricultural lean periods. Therefore, it is likely that other issues, such as wage-earning opportunities, individual household shocks, and the price of food—dictated by Indian prices—had a larger impact on food security than the seasonality of household production.

Under climate change, two inter-related outcomes could limit the ability of households to meet their food needs across all regions, but particularly in mountain areas. Reduced winter crop production due to lower post-monsoon precipitation would force households to reduce consumption from domestic sources and purchase more of their food. In addition, climate-induced food price volatility could require households to spend more of their income on food.

Figure 26. Terai population, average monthly kilocalorie consumption by source.
(Source: CBS, 2011)



Food consumption and sources

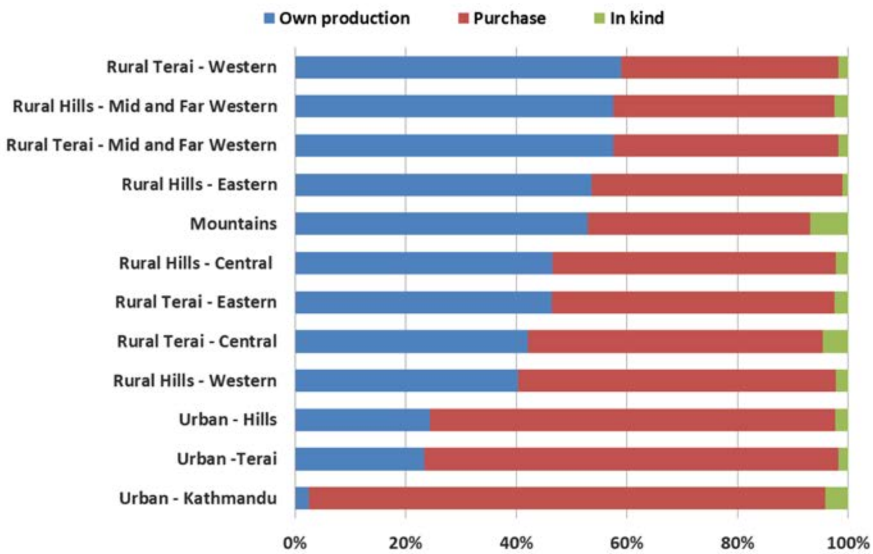
The main indicators of food consumption and sources are: food expenses (consumption of food in the past 7 days); sources of food consumed (own production/purchase/in-kind payments); expenditure on food.

Rice is the main source of food across Nepal. Indeed, most households across all regions in the country consume coarse and/or fine rice every day of the week. Maize is most common in hill districts all over Nepal, and wheat is most commonly consumed in the Mid- and Far-Western Development Regions. Finally, millet is consumed mostly in the hill and mountain areas.

The main crop in Nepal—rice—is highly sensitive to changes in precipitation. As shown earlier in this report, historical climate trends indicate an increase in monsoon precipitation leading to higher rainfall in key producing areas of eastern Nepal. This trend is projected to continue under climate change, but producing areas in western Nepal are likely to experience declines in rainfall that could result in lower rice yields, although some years with below-average rains are expected. This would push vulnerable households to rely more heavily on markets to obtain their food.

The majority of food is obtained through household's own production or purchases. These two sources account for at least 80% of all food in all regions (figure 27). Generally, in rural areas, there is a higher reliance on markets (especially for rice) in the mountain areas and in the

Figure 27. Most common food sources and climate sensitivities.
(Source: CBS, 2011)



Food source	Climate sensitivity
Own production	Erratic rainfall patterns could lead to floods and droughts that could affect crop production, and therefore the availability of food. Households across all regions obtain a significant proportion of their food from their own production. If production of poorer households decreases, they are likely to depend increasingly on markets.
Purchase	Across Nepal, the poor are highly market-dependent and purchase most of their food. Changes in production due to climate-related phenomena are likely to increase food prices, thereby reducing the ability of households to buy food.

Mid- and Far-Western Development Regions. This is because households in the mountainous and western parts of the country produce a deficit and so have to buy rice from markets. In the urban context, markets represent the main source of food (accounting for all food in the Kathmandu area, and over 90% of food sources in other urban areas). The high reliance on markets highlights the potential vulnerability of the Nepalese population to volatile food prices.

Household production provides the most common source of food in the Western, Mid- and Far-Western Development Regions of Nepal. Under a climate change scenario of lower winter precipitation in the western parts of the country, domestic production is likely to decline, resulting in detrimental impacts on food security. These regions already have low levels of caloric intake so climate risk could pose additional challenges to meeting food requirements.

In the eastern Terai and hill regions, domestic production also contributes a significant proportion of household consumption. Climate scenarios suggest that monsoon precipitation is likely to become more intense in eastern Nepal. Under more intense rainfall, two outcomes could affect food security. On the one hand, additional rain could improve yields, particularly for rice. Households would be able to sell their surplus and obtain additional income to purchase better foodstuff, thereby improving their diet quality. But, on the other hand, extreme rainfall events could have devastating impacts on crops, farms and infrastructure. Landslides and floods could also affect the ability of households to reach markets, which provide 40–50% of the food consumed in the eastern Terai and hills. What is more, the increasingly erratic and untimely nature of rainfall makes it difficult for the farmers to plan sowing and planting schedules, with potential adverse impacts on production.

Markets contribute to a significant proportion of food sources across all regions. Households in all districts rely on the market for almost 50% of their food needs—reliance on markets is higher in poor to very poor groups. The poorest households depend heavily on the market and use their cash income to purchase food. On average, households spend over two-thirds of their private consumption expenditure on food, but for poorer households the proportion of income spent on food can be closer to 80%. Poverty and food insecurity in Nepal are highly linked to the dependence on markets.

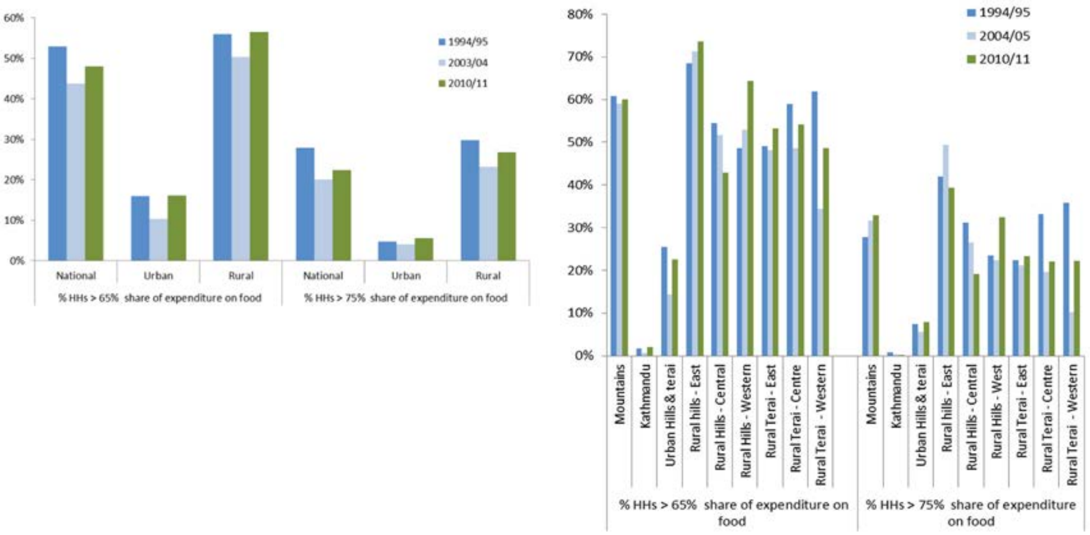
Despite significant increases in food prices, the food security situation in Nepal has been improving, as highlighted in the 'food security context' section on page 12. However, the percentage of total expenditure on food remains very high in the hills and mountains; especially in the Far-Western Development Region of Nepal. Here, over 40% of households are unable to meet their food needs with what they earn and rely on various coping strategies such as seasonal migration and in-kind food contributions, especially during the agricultural lean season. Therefore, households in these areas are highly vulnerable to price shocks.

There is also a significant concern that, for the poorest and most disadvantaged, rapid food price inflation may have significantly exacerbated food insecurity. An analysis of the proportion of the population with 'high' and 'very high' food expenditure indicates that amongst some of the poorest households, food price increases have indeed increased economic vulnerability to food insecurity and pushed a small proportion of households deeper into poverty (figure 28).

While the average proportion of expenditure that the poorest households make on food has reduced since the 2003/2004 NLSS, there are indeed a greater percentage of households spending a 'high' proportion on food (>65% of total expenditure). This level of expenditure on food creates significant economic vulnerability amongst households, especially those

Figure 28. Food expenditure trends.

(Sources: CBS, NLSS-I, II, and III)



living below or near the poverty line that are unable to cover their other essential needs. On the other hand, households living close to the poverty line will not be able to invest in productive assets or other activities to improve their long-term food security.

It was also found that the percentage of households spending a ‘very high’ proportion of their income on food (>75% of total expenditure) has also increased. This level of expenditure on food is of considerable concern—for poor households it indicates the potential erosion of existing assets and for households that are near the poverty line it means that some other basic living costs, such as health and education, may also be sacrificed to cover consumption needs. The rate of ‘high’ and ‘very high’ expenditure on food has increased similarly in both urban and rural areas. This is to be expected; in urban areas the poor rely more heavily on purchased food and therefore the poor are more vulnerable to food price increases, whereas in rural areas a greater percentage of the population is considered poor and thus the overall population is more vulnerable.

Under climate change, lower crop production (both from domestic production in Nepal and imports from India) could increase food prices. Additionally, more intense monsoons and landslides can complicate the transportation of food to remote areas, thereby increasing both transport costs and food prices simultaneously. Overall, this suggests that the poorest households, particularly in remote mountain areas, are highly vulnerable to climate-related price changes. This is due to the complex interactions between climate and markets, including price volatility because of lower crop production and transport costs, and local and external factors. These interactions render households vulnerable to climate-related price shocks.

Income

The main indicators of income are the different sources of income, types of profession and wealth groups.

Across Nepal, farming activities contribute more to income in the Far-Western Development Region and in the hill regions. Non-farm activities provide an important source of income in urban areas, particularly in the Terai. Remittances (money transfers) are important in all regions, although their contribution to total income is higher in the western hills and Terai.

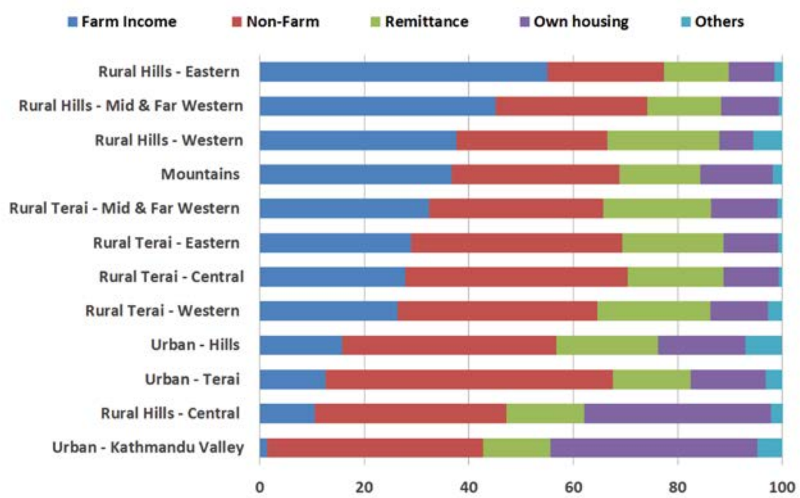
Wealthier households are more likely to earn remittances from overseas and, at the same time, earn more per capita. Overall, this means that remittances represent a greater percentage of total household income for wealthier families. However, because poorer households spend more of their income on food, remittances play a particularly important role in their food security. Finally, households living in their own housing[8], or renting out non-agricultural property like buildings, or acquiring assets and earnings from savings/deposit accounts, have additional income to spend on food, particularly in the Kathmandu valley and the central hills (figure 29).

Farm income is particularly sensitive to climate variability. As highlighted earlier (see figure 16), crop production is linked to changes in precipitation so erratic rainfall could result in unstable income sources. Farm activities are the most important source of income in the mountain and western, mid- and far-western hill regions of Nepal, where winter precipitation is expected to decrease with potentially devastating impacts on winter crop production and farm income. Reduced income could affect the ability of households in these regions to purchase sufficient food, and could result in negative coping strategies such as purchasing food of lower quality. As highlighted earlier (see figures 21–23), it is these regions that already have the lowest caloric intake per capita as well as poor diet diversity, so climate risks could exacerbate food security risks associated with diet quantity and quality.

Certain livelihoods are particularly vulnerable to food insecurity—often because food insecurity stems from poverty caused by the low income derived from the profession (figure 30). In particular, in both rural and urban areas, agriculture wage earners are the most likely to be poor. However, they are not the most likely to be food energy deficient due to high staple consumption (staples are relatively cheaper than other foods).

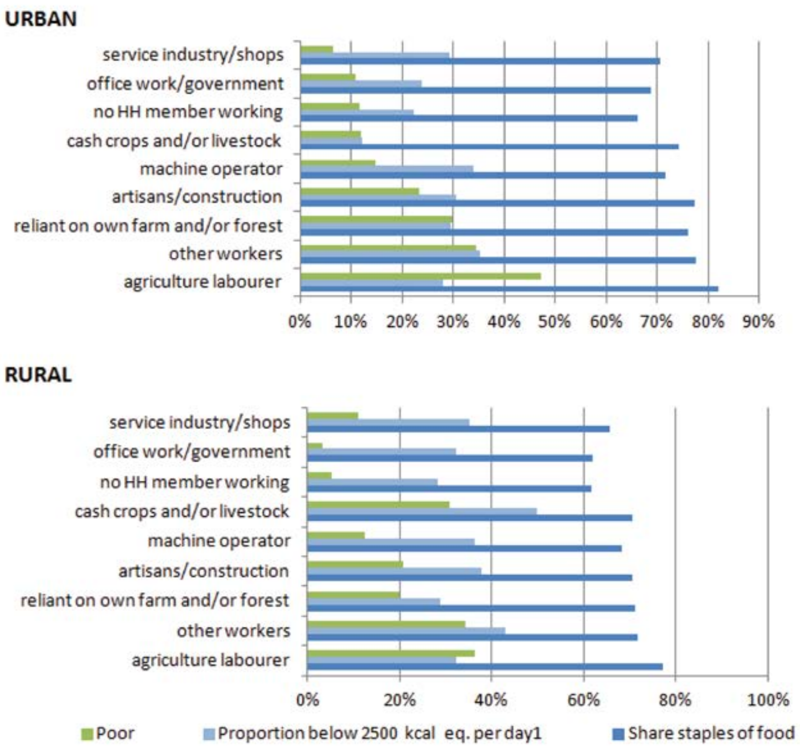
There is a strong correlation between income and food security (figure 31). Poverty is closely related to insufficient food consumption due to the high dependence on markets to meet food needs, especially in urban areas. Rising food prices could have undermined the gains made in poverty reduction and reduced purchasing power, thereby limiting the amount and variety that poor households can buy at market.

Figure 29. Income sources by region.
(Source: CBS, 2011)



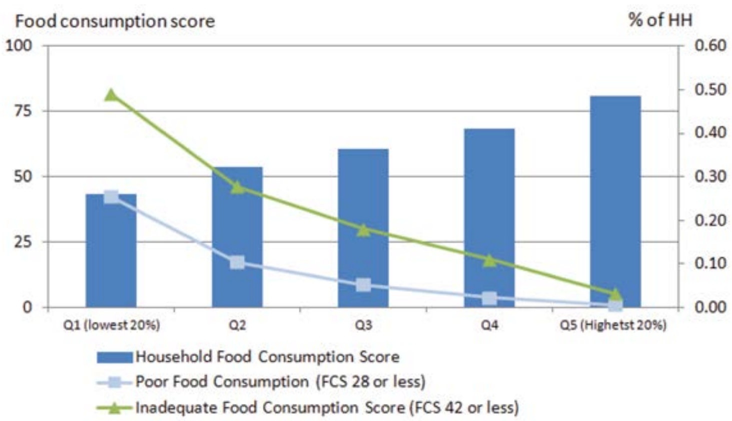
8 ‘Own housing’ refers to the income that a household would normally spend on rent but is saving due to its occupancy of rent-free dwellings.

Figure 30. Food security, poverty and climate sensitivities by profession.
(Source: CBS, 2011)



Income source	Climate sensitivity
Cash crops/livestock	Changes in rainfall patterns are expected to decrease both the quantity and quality of water available for crop and livestock production, resulting in lower quality crop yields, as well as lower livestock, meat and milk quality.
Own farm/forest	Agriculture in Nepal might be affected by erratic rainfall patterns, which could reduce growing season and yields.
Agriculture labourer	Agricultural labour is likely to be affected by seasonal and long-term changes in rainfall patterns. Labour availability under climate change is likely to become unpredictable, potentially lowering income for agricultural labourers

Figure 31. Income by wealth quintiles and food security.
(Source: CBS, 2011)



Managing climate risk

Food security is one of the most climate-sensitive sectors in Nepal. Indeed, the National Adaptation Programme of Action (NAPA; MoE, 2010) prioritizes agriculture and food security as one of the most vulnerable to the adverse effects of climate change and variability. It also prioritizes a combination of macro-scale technological and market-based solutions, as well as micro-scale resilience-building activities at the community level. Moreover, the top 3 of 9 NAPA priorities include an explicit food security component, highlighting the urgency and immediacy of addressing climate risk in this sector. NAPA recommends a combination of policies at different scales to reduce climate impacts. This analysis corroborates its finding and highlights that historical climate variability has had a negative effect on food security, particularly in the context of lower yields in areas that are already food insecure.

The negative effects of erratic precipitation might have been countered by adaptation measures taken by farmers, such as the slow change in choice of crops (including the substitution of barley for other crops) or planting dates. Such gradual adaptation measures occur at small spatial scales and cannot be captured by the models used in this analysis—because these used de-trended data. In this context, the reported impacts of climate on food security should be interpreted as the expected impact in the absence of adaptation measures (cf. Lobell and Field, 2007). The scale of adaptation therefore adds a level of uncertainty in estimating climate impacts on food security.

Eight food security and adaptation considerations, based on consultations with experts from various national institutions[9], are outlined below:

- **Adaptation to drought resulting from reduced winter rainfall through water management.** The results indicate that the mid- and far-western parts of the country are the most vulnerable to the negative impacts of more erratic rainfall and declines in winter precipitation. One of the key implications of this finding is that water management in areas where precipitation is becoming more intense (such as in the eastern Terai during the monsoon season) or more scarce (such as in the western parts of the country during the winter months) should be a priority for adaptation

How communities cope with climate risks

Communities manage risks associated with perceived climatic variability—especially crop failure, which affects livelihoods and incomes—through a number of initiatives. Across the mountain regions of the Nepal one of the most common coping strategies is crop substitution (particularly with potato, as seen by the rapid increase in potato production over the last few decades). Communities have also diversified their crops. Through crop diversification and alternative crop planting schedules, communities have reduced the risks associated with losing an entire plantation during an extreme weather event.

In response to more erratic rainfall patterns, migration has also been an important coping strategy. Migration can occur seasonally (during the lean agricultural season), from rural to urban areas, and to other countries by those in search of non-agricultural employment.

Other strategies have included land and water resource management techniques (such as land conservation and the construction of irrigation ponds and canals) to reduce environmental degradation and enhance resilience to drought and flood risk.

See also Pokharel and Byrne (2009).

9. In December 2011, a workshop was held with various organizations to share the preliminary results of this analysis and identify key climate change adaptation strategies to enhance food security (see Annex I for an overview of the method used in this analysis). Participants included climate change and/or livelihood experts from the following Nepalese organizations: ISET-Nepal, Department of Hydrology and Meteorology, Ministry of Agriculture and Cooperatives, ICIMOD, NDRI and the Institute for Integrated Development Studies; along with international development charity Practical Action.

Photograph 4. Through terracing activities, communities in the Far-Western Development Region of Nepal are working to minimize disaster risk associated with floods and land-slides. (Credits: WFP/Deepesh Shrestha)

strategies. One such strategy might be supported through the installation of irrigation infrastructure and water optimization practices (such as drip irrigation), particularly in the Mid- and Far-Western Development Regions. Drought risk management strategies might be enhanced through the introduction of drought-tolerant crops and crop varieties.

- **Adaptation to floods and landslides resulting from erratic (and potentially more intense) summer rainfall through water management.** The analysis highlights that summer crops have experienced yield reductions associated with super-optimal temperature and erratic precipitation in recent years. Strategies to ensure sustainable crop production under climate variability should focus on those crops that have experienced the largest yield losses due to climatic factors. Rice—the main staple in Nepal—is especially sensitive to changes in rainfall. The system of rice intensification (SRI), which consists of transplanting individual, young seedlings in wide spaces with alternate wet and dry periods to increase rice yields, can also provide a mechanism for enhancing rice production under climate change (Singh, 2008).

Other specific priorities that should be addressed in the context of increasing supply variability incorporate a water management component, including the expansion and refurbishment of irrigation and water storage infrastructure; capacity building for more water-efficient cropping practices; and the adoption of flood-resilient cropping systems and crop varieties (Bartlett et al., 2010).

- **Adaptation to climate-induced market risks.** Beyond agricultural production, at-risk populations are also highly dependent on markets and vulnerable to volatile food prices. In the context of food price stabilization, the Nepal Food Corporation (www.nfc.com.np) has been engaged in providing food in remote mountain districts at Government rates by subsidising transport costs. This type of initiative can help mitigate the negative effects of climate risk on food prices associated with higher transport costs. The monsoon limits the transportation of food in many areas of the country and private traders tend to adopt risk adverse strategies such as pre-monsoon commodity stockpiling which affect food prices. Traders opt not to re-stock during the monsoon period even when food stocks are depleted. This is due to high transportation costs during these periods with the added risk that they will be unable to sell their stocks once routes become accessible again as competitors will be able to sell against lower prices (WFP, 2010). Under climate change, more intense monsoons and frequent landslides complicate the ability of traders to gauge the amount of food to pre-position. Proper local storage facilities and food stocks can provide a buffer against food insecurity in deficit months, and can reduce dependence on markets during the lean periods (WFP, 2010). The implementation of early warning systems can provide timely information about roads/routes that are unreachable due to climate-related disasters, ensuring that remote populations can continue to access markets.

  Interventions to improve food security at the national level should include policies to improve access to markets (by improving transport and road infrastructure). Additional innovative mechanisms such as insurance schemes can also help reduce some of the negative effects of climate on food security (Moench, 2010). Finally, livelihood diversification strategies can play a key role in increasing the purchasing power of households, thereby reducing their vulnerability to price shocks.

- **Asset creation and disaster risk management.** At the community level, social protection mechanisms through conditional asset transfers, including food/cash-for-work interventions, can enhance resilience. For example, slope stabilization and landscape management schemes can improve the stability of fragile environments, particularly in the hill and mountain areas of the country. Similar activities might also support disaster risk-management at the community level through, for example, the construction of disaster mitigation infrastructure such as embankments, dykes and dams, along with other infrastructure to improve access to facilities such as roads and mountain trails.

- **Support for livelihood and income diversification.** Key crops are highly sensitive to climatic variability. For households that depend heavily on farm activities for their income— particularly in the hill and mountain regions—strategies for livelihood and income diversification are critical to ensuring resilience. For example, migration (both seasonal and permanent) has become an important source of household income for at-risk populations. Increasing voluntary labour mobility is a low-cost, low regret approach that contributes to the adaptive capacity of communities. This is achieved through networks that are used to exchange goods, services and information while also giving at-risk populations the opportunity to adapt based on their needs (Barnett and O'Neill, 2012). Support to additional income sources, such as wage labour, skilled non-farm activities and forest management can similarly lead to improved livelihoods.

- **Capacity building at the Government and community levels.** Efforts to reduce climate impacts should also incorporate a strong capacity building and resource mobilization component at the Government and community levels (Department of Water Induced Disaster Prevention (DWIDP), 2007; UNDP, 2009b; MoE, 2010). This involves awareness-raising campaigns, as well as developing analytical tools to ensure that risks and vulnerabilities are identified and mapped. Through this type of analysis, early warning systems can contribute to efforts to reduce the food security impacts of extreme weather events such as droughts and floods.

- **Strengthening climate information for early warning systems.** An effective early detection and warning system for severe or abrupt climate variability is an important tool for climate risk management. Integrating this information into existing early warning systems for food security can provide an additional layer of information for better food security and adaptation planning. The Nepal Food Security Monitoring System (NeKSAP), for example, was established by WFP in 2002. The system is currently being institutionalized within the Ministry of Agriculture Development under the strategic guidance of the NPC. It collects, consolidates and analyses food security data including household food security, climate risks, emerging crises, markets, and nutrition across Nepal. The information produced through the NeKSAP is communicated to decision makers in order to achieve coordinated, appropriate and timely action by relevant stakeholders, including the Government, International Non-Governmental Organizations, United Nations and donor agencies.

- **Management of uncertainties associated with long-term climate change.** Adaptation options should also consider a range of uncertainties associated with climate variability and the timescales of climate impacts. For example, in the medium-term, glacier melt would result in glacier lake outburst floods as well as an increase in water availability, but in the long-run the amount of water available would decrease significantly if the glaciers do not recover. However, because the long-term drought risk associated with GLOFs is unlikely to be for decades, the short-term benefits of increased run-off are likely to delay proactive long-term adaptation measures (Bartlett et al., 2010). In planning for adaptation within the context of GLOFs, it will be important to consider both flood and drought risk simultaneously.

Conclusions and recommendations

Food security is highly sensitive to climate risks in Nepal. Recent climate-related events and trends have highlighted the potential impact of droughts, floods, and glacial melt on crop production, access to markets, and income from climate-sensitive activities (including rainfed agriculture).

Rainfall is one of the key climatic variables affecting food security in Nepal. This analysis shows that rainfall is highly variable across the country, and throughout the year. Recent data highlight that rainfall intensity is increasing, especially in the eastern parts of the Terai. Conversely, rainfall has been both declining and more erratic during the winter months, particularly in the Mid- and Far-Western Development Regions. Shifts in the timing of rainfall have also been recorded, suggesting more erratic and unpredictable rainfall.

This analysis suggests that food security indicators in Nepal, including crop yields, food prices and livestock products, are influenced by recent climatic trends. The impact of these climate trends was likely offset by adaptation measures at the community level, including the selection of alternative crops (Gurung et al., 2010), application of fertilizers (Lobell and Field, 2007) and livelihood diversification (Regmi, 2007)—but the magnitude of these effects is uncertain and difficult to quantify.

Historically, the most discernible impact of climate trends on crop production has been that of precipitation. Among the main crops, paddy rice is the most sensitive to changes in annual precipitation patterns. Additionally, crops respond negatively to declines in precipitation during the growing season, with winter crops being especially sensitive. Temperature also has an impact on food production although it is lower.

The results also indicate that climate trends may have contributed to some variations in food prices, although the results are less conclusive due to the influence of imports, particularly from India, on food prices.

Historical climate trends, particularly precipitation, are also correlated to livestock products. Significant changes in precipitation patterns, particularly in the mountain and hill regions, could have a detrimental impact on rearing livestock, resulting in loss of income and purchasing power. However, it is also likely that trends in livestock production have been influenced by social factors such as out-migration by people who have traditionally relied on livestock for their livelihoods.

A detailed analysis of livelihoods reveals that regional patterns of food insecurity, particularly in the most vulnerable areas of mid- and far-western Nepal, are highly sensitive to climate trends. It is likely that climate change will exacerbate livelihood vulnerabilities and food insecurity trends in the most at-risk areas. Efforts to reduce climate impacts on food security in Nepal should therefore prioritize these regions.

Furthermore, food security is highly seasonal—especially in the mountainous parts of mid- and far-western Nepal. In the winter months, households in these regions are highly dependent on purchased food and in-kind contributions. One of the key findings of this analysis is that winter rainfall is becoming more erratic, and declining over the long term. This trend could force the most vulnerable households to purchase even more food, and to spend more of their limited income on food.

Through consultation with national experts from different organisations, this report identifies seven recommendations to enhance food security and resilience, and manage climate-related risks:

- **Adaptation to drought resulting from reduced winter rainfall through water management.** The mid- and far-western parts of Nepal are the most vulnerable to the negative impacts of more erratic rainfall and declines in winter precipitation. Water management strategies, supported by the introduction of drought-tolerant crops and crop varieties can play a critical role in reducing the vulnerability of at-risk populations.

- **Adaptation to floods and landslides resulting from erratic (and potentially more intense) summer rainfall through water management.** Strategies to ensure sustainable food security under a scenario of increased precipitation should focus improving water management practices.

- **Adaptation to climate-induced market risks.** At-risk populations are also highly dependent on markets and vulnerable to volatile food prices. In this context, food stabilization during shocks (through subsidies) and food stocks can provide a buffer against food insecurity. Improving infrastructure is also likely to enhance access to markets. The implementation of early warning systems can provide timely information about roads/routes that are unreachable due to climate-related disasters, ensuring that remote populations can continue to access markets. Other innovative strategies, such as weather-index insurance schemes, can also protect vulnerable farmers against the negative impacts of climate variability.

- **Asset creation and disaster risk-management.** At the community level, conditional asset transfers including food or cash-for-work interventions, such as slope stabilization, landscape management and disaster mitigation infrastructure, can reduce both disaster and climate-related risks. Ensuring vulnerable communities have access to social protection is also critical to enhancing resilience.

- **Support to livelihood and income diversification.** Given the high reliance on rainfed agriculture, strategies for livelihood and income diversification are critical to ensuring resilience. Training vulnerable people to engage in different activities, such as wage labour, skilled non-farm activities and forest management can help improve livelihoods and reduce their sensitivity to climate impacts.

- **Capacity building at the Government and community levels.** Efforts to reduce climate impacts should also incorporate a strong capacity building and resource mobilization component at the Government and community levels through awareness-raising campaigns, as well as by developing analytical tools to ensure that risks and vulnerabilities are identified and mapped.

- **Strengthening climate information for early warning systems.** An effective early detection and warning system for severe or abrupt climate variability is an important tool for climate risk management. Integrating this information into existing early warning systems for food security can provide an additional layer of information for better food security and adaptation planning.

- **Management of uncertainties associated with long-term climate change.** Adaptation options should also consider a range of uncertainties associated with climate variability and the timescales of climate impacts. Some climate risks, such as glacier melt, could lead to increased flooding (in the medium-term) and increased drought (in the longer term). In managing uncertainties, multiple risks need to be considered simultaneously.

Vulnerability profile of Nepal by region

These food security adaptation recommendations—identified in consultation with partners—must be considered in relation to the changing levels of vulnerability across the different regions of Nepal. To better understand the context of vulnerability, the following table summarizes the key climate and food security issues by analytical domain.

	Analytical domain	Geographical location	Vulnerability
Mountains and rural hills	**Mountains**		**Food security:** Poorest food consumption score in Nepal (FCS=55), and high proportion of food poor households (31%) **Rainfall trend:** Decline in rainfall in mid- and far-western mountains **Seasonality of food security:** High reliance on in-kind contributions and purchases in the agricultural lean seasons **Food source:** High reliance on domestic production throughout the year (~50%). Highest reliance on in-kind contributions during the agricultural lean seasons **Main income source:** High reliance on both farm (~40%) and non-farm income (~30%) including non-timber forest products and remittances
Mountains and rural hills	**Rural hills Eastern**		**Food security:** Below-average food consumption score (FCS=59) and below-average proportion of food poor households (16%) **Rainfall trend:** Increase in rainfall, particularly in the post-monsoon season **Seasonality of food security:** High reliance on markets in the pre-monsoon months **Food source:** High reliance on domestic production (~50%) **Main income source:** Mainly farm income (>50%), cash crops
Mountains and rural hills	**Rural hills Central**		**Food security:** Below-average food consumption score (FCS=56) and above-average proportion of food poor households (27%) **Rainfall trend:** Increase in rainfall, particularly in the post-monsoon season. Also increasingly erratic rainfall patterns **Seasonality of food security:** High reliance on markets in the pre-monsoon months **Food source:** High reliance on markets (~50%) and domestic production (~40%) **Main income source:** High reliance on non-farm (~40%) and own housing income (~40%)

	Analytical domain	Geographical location	Vulnerability
Mountains and rural hills (continued)	**Rural hills Western**		**Food security:** Above-average food consumption score (FCS=64) and below-average proportion of food poor households (21%) **Rainfall trend:** Decrease in rainfall **Seasonality of food security:** High reliance on markets in the pre-monsoon months **Food source:** High reliance on markets (~60%) **Main income source:** Farm income (~40%), and high reliance on remittances (~20%)
Rural Terai	**Rural hills mid- and far-western**		**Food security:** Below-average food consumption score (FCS=59) and highest proportion of food poor households (42%) **Rainfall trend:** No discernible long-term trend in annual rainfall but recent decrease in winter rainfall **Seasonality of food security:** High reliance on markets in the pre-monsoon months **Food source:** High reliance on domestic production (~60%) **Main income source:** Mainly farm income (>40%)
	Rural Terai Eastern		**Food security:** Above-average food consumption score (FCS=63) and below-average proportion of food poor households (16%) **Rainfall trend:** Increase in intensity of summer monsoon rainfall **Seasonality of food security:** Higher reliance on markets after the second agricultural lean season (February to March) **Food source:** High reliance on both domestic production (~45%) and markets (~45%) **Main income source:** Non-farm income (~50%)
	Rural Terai Central		**Food security:** Above-average food consumption score (FCS=63) and below-average proportion of food poor households (23%) **Rainfall trend:** Increase in intensity of summer monsoon rainfall **Seasonality of food security:** Higher reliance on markets after the second agricultural lean season (February to March) **Food source:** High reliance on both markets (~50%) and domestic production (~40%) **Main income source:** Non-farm income (~40%), high reliance on remittances (~20%)

	Analytical domain	Geographical location	Vulnerability
Rural Terai (continued)	**Rural Terai Western**		**Food security:** Above-average food consumption score (FCS=65) and below-average proportion of food poor households (21%) **Rainfall trend:** Decrease in rainfall **Seasonality of food security:** Higher reliance on markets after the second agricultural lean season (February to March) **Food source:** High reliance on domestic production (~60%) **Main income source:** Non-farm income (~40%), high reliance on remittances (~20%)
Rural Terai (continued)	**Rural Terai mid- and far-western**		**Food security:** Below-average food consumption score (FCS=58) and high proportion of food poor households (31%) **Rainfall trend:** Decrease in rainfall **Seasonality of food security:** Higher reliance on markets after the second agricultural lean season (February to March) **Food source:** High reliance on domestic production (~60%) **Main income source:** Farm (~30%) and non-farm income (~30%), high reliance on remittances (~20%)
Urban	**Urban Terai**		**Food security:** Above-average food consumption score (FCS=71) and below-average proportion of food poor households (18%) **Rainfall trend:** No discernible long-term trend (geographically variable) **Seasonality of food security:** No significant seasonal difference in food security **Food source:** High reliance on markets (~80%) **Main income source:** Non-farm income (~50%)
Urban	**Urban Hills**		**Food security:** Second highest food consumption score (FCS=76) and low proportion of food poor households (9%) **Rainfall trend:** No discernible long-term trend (geographically variable) **Seasonality of food security:** No significant seasonal difference in food security **Food source:** High reliance on markets (~80%) **Main income source:** Non-farm income (~60%), high reliance on remittances (~20%)

	Analytical domain	Geographical location	Vulnerability
Urban (continued)	**Urban Kathmandu**		**Food security:** Highest food consumption score (FCS=78) and lowest proportion of food poor households (6%) **Rainfall trend:** No discernible long-term trend **Seasonality of food security:** No significant seasonal difference in food security **Food source:** High reliance on markets (over 90%) **Main income source:** High reliance on non-farm (~80%)

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Annex 1: Data and methods

Background

The analytical method carried out for this study consisted of three components:
1. A descriptive analysis to establish a baseline against which vulnerability to future risks can be assessed.
2. A dynamic analysis to evaluate the relationship between historic and current climatic variability and food security indicators.
3. A workshop with a number of partners and organizations to validate the results and identify priority adaptation interventions.

The first two components of the analysis provide complementary information to determine the relationship between climate variability, food security and vulnerability across Nepal. The third component of the method provides a forum for the exchange of ideas and prioritization of adaptation options that are nationally relevant for the context of Nepal.

Baseline vulnerability analysis—descriptive analysis

The aim of this component of the analytical method was to identify spatial patterns of vulnerability as well as the priority areas for interventions to mitigate the impacts of climate risk on food security.

Data

The data for the baseline vulnerability analysis were mainly taken from the Nepal Living Standard Survey (NLSS-III) 2010/2011. These surveys are carried out by the Central Bureau of Statistics (CBS) with technical support from other agencies including the World Bank and the World Food Programme (WFP) of the United Nations. The data were obtained through household surveys that aimed to track changes in the living standards of the Nepalese population since 1995/1996.

Each survey follows the World Bank's Living Standards and Measurement Study (LSMS) method, which uses standardized multi-topical household questionnaires. Households are selected through a two-stage stratified sampling scheme so as to provide representative data across regions and socio-economic conditions. In order to provide a reliable track of changes in living standards, the NLSS interviews also involve households that were included in previous surveys. Under the NLSS-III initiative over 7 020 households were enumerated. The data collected under these surveys is the most reliable household level data in Nepal.

New indicators were added to the NLSS-III, including vulnerability to shocks, food consumption, income sources, coping strategies, and market dependence and access. This type of information is useful in providing a baseline analysis of vulnerability to climate impacts. In particular, household level data can provide sufficiently disaggregated information to understand the spatial distribution of vulnerability against which to measure progress in risk management.

NLSS-III provides a baseline of the living standards (including the food security situation) in Nepal under normal circumstances. Exploring the outputs of survey provides information about the sensitivities of different livelihoods to climate change and consequently the relationship between livelihoods vulnerability and climate. The purpose of integrating climate information into the NLSS-III is to understand how this baseline might either change or be affected by climate variability; and, in particular, how specific regions and populations could be affected by these changes.

Method

The aim of descriptive component of this analysis was to represent the potential vulnerabilities of food security to climate variability in Nepal through maps and other visual outputs. For the descriptive assessment, relevant variables that are climate sensitive were identified in the NLSS data (questionnaires, secondary data and livelihood profiles were examined). The relevant parameters from these questionnaires, secondary data and other sources were selected, and their specific vulnerabilities to climate variables were described. The qualitative assessment provided information to identify the spatial patterns of vulnerability, as well as the factors that render regions vulnerable.

Vulnerability profiles were carried out for each analytical domain to understand the climate sensitivities of food security. Twelve analytical domains are used for this analysis:

- mountains
- rural hills—eastern
- rural hills—central
- rural hills—western
- rural hills—mid- and far-western
- rural Terai—eastern
- rural Terai—central
- rural Terai—western
- rural Terai—mid- and far-western
- urban—Kathmandu valley
- urban—hills
- urban—Terai

Each of these analytical domains contains approximately 30–35 clusters of households, located in different districts, allowing for a generalization of food security in the area. Some districts belong to two analytical domains so it is not possible to map the livelihood and food security indicators accurately. However, for the purposes of this analysis, maps highlighting the districts that belong to each analytical domain are included to illustrate trends.

To understand the climate sensitivities of food security and livelihoods, this analysis includes the identification of household sources of food and income that are sensitive to climate factors. These sources of food and income are descriptively analysed to determine how and why they are sensitive to climate and climate change.

This analysis of food sources provided information on the impact of climate change on household consumption and corroborated the analysis of the income sources. These data were used to identify who is vulnerable to climate change and in what ways.

This information was examined at district and regional levels to determine the geographical distribution of vulnerability that can be evaluated in conjunction with climate information to show where the vulnerabilities might be highest. The outputs of this analysis included maps to highlight the relative vulnerability of different regions to climate change in the context of Nepal.

Other similar food security data, such as the source of food or the consumption of food were obtained from the NLSS-III data and compared to climate scenarios and data in the same way. It is possible to identify the sources of income that are climate-sensitive (agriculture and livestock raising) and identify the proportion of climate-sensitive incomes according to geographical region. Other food security-related data such as the food consumption score, which illustrates the status of food security by region can also be quantified and plotted by analytical domain. This type of information highlighted the co-incidence of exposure, sensitivity and coping capacities.

Long-term statistical analysis—dynamic analysis

The aim of the long-term statistical analysis was to evaluate the temporal relationship between historic and current climate and food security, and to evaluate the correlations between climate and food security trends at the national and sub-national scale. Most assessments of climate impacts on food security focus on production—the aim of this analysis was to analyse potential impacts on other food security indicators.

Data and data quality

Inter-annual and seasonal long-term precipitation and temperature data at the national level were obtained from re-analysis and gridded station data (McSweeney et al., 2010; also Kalnay et al., 1997; Matsuura and Willmott, 2007). Daily precipitation data at the regional level were obtained from a gauge-based analysis of daily precipitation collected under the Asian-Precipitation — Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) project (Xie et al., 2007). Crop production, area, and yield data were obtained from MoAC (2009, 2010). Livestock production data were also collected from MoAC (2008). A summary of data collected and data sources is shown in Annex 2.

Food security indicators were collected from the MoAC Statistical Yearbooks (2008–2010) which provide yearly national-level information on agricultural production (crops, livestock and fisheries), food prices and livestock products for the period 1984–2008. These statistics are considered to be the most reliable and accurate at the country level in Nepal. Data were collected and validated by various units under MoAC, including the NARC as well as the individual Departments of Agriculture, Livestock Services, Co-Operatives, and Food Technology and Quality Control along with other related governmental and non-governmental agencies. The statistics collected in the MoAC Statistical Yearbooks are relevant to the purposes of this study as they provide reliable long-term information about crop production, one of the key components of food security.

Longer term country-level annual crop production statistics for the period 1965–2009 were obtained from the statistics division of the FAO—FAOSTAT (faostat.fao.org/). Data were also collected through collaboration with other national governments that regularly provide statistics in the form of answers to FAO questionnaires. Missing values, particularly in the early part of the record, were estimated based on a trend analysis. These data are the longest standardized and reliable dataset on crop production at the country level.

Sub-national (district-level) agricultural statistics (crop production, area and yield) for the period 1984–2006 were obtained from the FAO-RDES (2006)—online at faorap-apcas.org/nepal.html—which collects standardized agricultural and food security data through collaboration with the CBS. Agricultural data were more easily available than other data, because agricultural production statistics are considered to be highly important for social and economic planning in the context of Nepal (FAO-RDES, 2006). The CBS is therefore responsible for collecting relevant and timely statistics, and for disseminating this information by collaborating with technical agencies such as the Asian Development Bank and FAO. This dataset was particularly relevant to the purposes of this study as it allowed for analysis of spatial relationships between food production and climate parameters.

Market price data for food items are collected fortnightly from 21 markets across Nepal by the Agribusiness Promotion and Marketing Development Directorate of the MoAC.

Nutrition data—a descriptive component of food utilization and food security more generally—are not available on a yearly basis for Nepal. The most reliable source of nutrition information is the Demographic and Health Survey data (DHS, online at http://www.measuredhs.com/). DHS data were available at irregular intervals (1987, 1996, 2001, 2006, and 2011).

Additionally, nutritional impacts are not felt immediately after a particular event (for example, drought or flood) but manifest over the long run. This means that in order to evaluate the relationship between climate parameters and nutrition impacts, longer time series were be needed. These data were therefore not included in the final study.

Country level meteorological data for the period 1960–2006 were collected from the UNDP/University of Oxford Climate Change Country Profiles (http://country-profiles.geog.ox.ac.uk/). This is centralized and processed climate information from a number of datasets, presented in a standardized format. Temperature data were processed by re-analysing datasets from the United States National Centers for Environmental Prediction (NCEP, http://www.ncep.noaa.gov/) (cf. Kalnay et al., 1996). Gridded station precipitation data were processed from the University of Delaware climate datasets; online at http://climate.geog.udel.edu/~climate/html_pages/Global_ts_2007/README.global.p_ts_ 2007.html (cf. Matsuura and Willmott, 2007). These data have been validated in collaboration with national meteorological agencies and provide a reliable estimate of historical temperature and precipitation at the country level. The data also provide a useful time series to examine climate-related trends across the country.

Daily precipitation data at the regional level were obtained by averaging station data collected under the APHRODITE project. Online at: http://www.chikyu.ac.jp/precip/products/index.html. For Nepal, daily precipitation data have been obtained from the Department of Hydrology and Meteorology—the national meteorological agency of the country—and represent the most reliable source of long-term precipitation information at regional level in Nepal.

Weather station data were also collected for stations that have been uninterruptedly active since 1995 from the Department of Hydrology and Meteorology. Overall, data were collected from 46 weather stations in 43 districts across all the regions and ecological zones of Nepal. These data allowed for an analysis of climate and food security trends at district level and provided an overall picture of spatial differences across the country.

Data at the national level were initially analysed to identify broad patterns. The results were then complemented and corroborated by sub-national (regional and district-level) analyses to identify the parts of the country where historical climate variability and food security indicators have the strongest correlation.

The purpose of the complete analysis was to identify vulnerability and food insecurity correlations with climatic factors. The results presented in the full analysis should therefore be interpreted as the inferred impact of climate variability on food security indicators in the absence of development and adaptation interventions. Non-climatic factors that are critical in determining food security were not included as they were beyond the scope of this study—socio-economic determinants of vulnerability such as caste/ethnicity, conflict, gender, entitlements to land and other resources, and governance considerations could be incorporated in a comprehensive vulnerability assessment.

Trend analysis

In order to evaluate the relationships between the time series for food security indicators and climate, data were de-trended based on a first-difference time series (that is, the differences in value from one year to the next). This method has been used in other studies to minimize the influence of gradual inter-annual changes associated with changes in crop management (for example, Nicholls, 1997; Lobell et al., 2005). Correlations between food security indicators (yield, food prices, livestock products) and climate variables (precipitation, temperature) were evaluated using Pearson's correlation analysis. A simple linear regression was also calculated to identify the most relevant climate parameter for each crop in the different districts. Regression analyses help to identify the relative contribution of climate parameters on changes in food security indicators (Joshi et al., 2011).

While an ex-post empirical study cannot attribute directions of causality, this study assumes that changes in climate factors resulted in yield changes, and not vice versa (Lobell and Field, 2007). It also assumed inter-annual changes in crop and livestock management regimes were not correlated with climate, or were caused by climate (Kaufmann and Snell, 1997), and that errors in data collection were independent of temperature and precipitation.

The use of models derived from inter-annual variations assumes that food security indicators respond to both gradual (long-term) and extreme (short-term) climate variations. However, the models do not consider the impact of adaptation measures. Adaptation benefits are expected to lag behind climate trends because of the disaggregated nature of decisions and interventions to reduce adverse climate impacts.

Significance of statistical relationships

The significance of the statistical relationships was evaluated by calculating the p-value associated with the correlations. A threshold of 10% ($p \leq 0.1$) was used to determine whether a statistical relationship was significant or not.

In order to control for spurious associations, the correlation between Δprecipitation and Δtemperature was considered. Given that there was a slight, but statistically significant, correlation, multiple linear regressions were also conducted to determine if either of the climate variables was redundant. These regressions were also used to evaluate the relative importance of climate parameters, relative to non-climatic factors which were not considered for this study. The dependent variable was Δyield, and the independent variables considered were Δprecipitation and Δtemperature (decided by the stepping criteria for entry and removal while regressing). The results indicated that Δprecipitation was the most important variable for most indicators in most districts, but including Δtemperature contributed to the explanatory power of the models.

Workshop and validation with key organizations

The aim of this component of the method was to engage key agencies in validating the results and to identify priority adaptation interventions. This component of the method provides a forum to engage key actors and ensure that nationally relevant issues are addressed.

A workshop was held at the WFP office in Nepal on 5–9 December, 2011. Participants included the members of various government agencies (including the Department of Hydrology and Meteorology, NPC and MoAC), as well as local experts from intergovernmental and non-governmental organizations such as ICIMOD, Practical Action, CARE International, ISET-Nepal and NDRI.

During the workshop, participants were asked to form groups to discuss: (i) the validity of the results; (ii) the additional analysis that may be required; and (iii) the adaptation implications of the analysis. Each group appointed a scribe to record the discussion before presenting the results to the rest of the participants. Following the group discussions, participants were asked to cluster the feedback into key follow-up actions which have been incorporated in the final version of the report.

Annex 2: Data sources

Long-term statistical analysis

Country-level data	Source
Long-term monthly temperature trend	NCEP (re-analysis data) Reference: Kalnay et al. (1996) Department of Hydrology and Meteorology Reference: DHM (2011)
Long-term monthly precipitation trends	University of Delaware (gridded station data, 0.5° × 0.5°) Reference: Matsuura and Willmott (2007) Department of Hydrology and Meteorology Reference: DHM (2011)
Number of people affected by climate-related disasters	The International Disaster Database Reference: EM-DAT (2011)
Crop production statistics	Ministry of Agriculture and Cooperatives Reference: MoAC (2009)
Food commodity price statistics	Agribusiness Promotion and Marketing Development Directorate Reference: ABPMDD (2012)

District and regional-level data	Source
Long-term temperature trend	NCEP (re-analysis data) Reference: Kalnay et al. (1996) Department of Hydrology and Meteorology Reference: DHM (2011)
Long-term monthly precipitation trends	APHRODITE (gauge-based analysis of daily precipitation rates) Reference: Xie et al. (2007) Department of Hydrology and Meteorology Reference: DHM (2011)
Crop production statistics	Ministry of Agriculture and Cooperatives, FAO Regional Data Exchange System Reference: MoAC (2012), FAO-RDES (2006)
Food commodity price statistics	Ministry of Agriculture and Cooperatives Reference: MoAC (2012)

Baseline vulnerability assessment

All baseline vulnerability data were obtained from the NLSS-III (CBS, 2011).

Annex 3: Challenges and lessons learnt

The analytical method presented here highlights some of the challenges and limitations associated with trend analysis of climate impacts on food security.

Data collection issues

The main challenge remains the collection of long-term weather station data. Precipitation and temperature data from weather stations in Nepal are centralized and managed by DHM. Apart from a few publications which include long-term data from a handful of stations, the majority of data are not shared with the public. Accessing this information often involves purchasing yearly data for individual stations. The data used here were obtained through an ongoing collaboration between WFP and the Government of Nepal to analyse food security in the country.

An additional challenge was the collection of long-term statistics at district level, particularly for indicators such as food commodity prices. Agricultural data in Nepal are collected by the CBS and MoAC. These data have been distributed through publications and collaboration with international organisations such as the FAO. The main challenge, however, is that long-term data do not exist for certain indicators.

Most time series data focus on production indicators that are easier to quantify. Other important information such as caloric requirements compared to caloric availability, or the average percentage of income spent on food, are not routinely collected as they require more complex assessments.

Nutrition data are particularly difficult to obtain. The most comprehensive data on nutrition statistics in Nepal are the Demographic Household Surveys. However, these data are not available on a yearly basis. Additionally, climate impacts on nutrition can only be felt over the long run, so the impacts are difficult to quantify.

Data processing

The main limitation in processing data for Nepal is the difference between the Gregorian and the official Nepali (Bikram Sambat) calendars. The majority of meteorological data are aligned to the Gregorian calendar. In contrast, time series data collected by the Government ministries and departments are aligned to the Nepali calendar. The data need to be processed so that the calendars used coincide.

Other issues include variations in the naming of districts due to variations in spelling, while writing the pronunciation of the Nepali names in Latin letters. Datasets were processed so that the English spelling of the districts was consistent with the district names provided under the Global Administrative Units Layer developed by FAO and used for WFP's planning purposes.

Assessing the contribution of climate factors to food insecurity

Some factors that are affected by climate are difficult to quantify but are critical to understanding food security in vulnerable settings. These factors include, among others, adaptation strategies implemented by farmers (which, in turn, could be a response to climatic changes and could therefore lag behind climate trends), access to markets (which is very specific to households), and livelihood assets (which are also very specific to households). These data are not available as long-term time series and cannot be considered in this type of analysis. However, including this type of information is critical in understanding food security as well as overall vulnerability trends.

Non-climatic factors also need to be considered to accurately determine the conditions that influence food security trends. For example, climate trends within Nepal alone are unlikely to influence food prices as these are also influenced by imports from India and other countries. Identifying the non-climatic factors that have the greatest impact on food security indicators would provide a more nuanced understanding of climate impacts on food security.

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