Climate risk and food security in Nepal:

Analysis of climate impacts on food security and livelihoods

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Analysis of climate impacts on food security and livelihoods*

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Foreword

Nicole Menage, Country Director, World Food Programme, Nepal

Food security is a priority issue in Nepal. In spite of recent progress, Nepal is amongst the most at-risk countries in the world in terms of prevalence of stunting and wasting: 42 per cent of children under 5 are stunted and 31 per cent are underweight. The situation is more severe in some communities of the Far and Mid-Western regions, where stunting rates can reach above 70 per cent and wasting exceeds 20 per cent.

A set of interrelated factors helps to explain the high level of food insecurity, including the combination of the global economic and food price crises and frequent natural disasters. Increasingly, empirical evidence suggests that climate variability and extremes have an adverse impact on the food security of the most vulnerable communities and should therefore be a key component of a strategy to address food security problems.

Given the clear impact of climate on food security, WFP has made addressing the impact of climate change on hunger a priority in the most vulnerable countries. WFP's strategy to address climate change issues emphasises the importance of enhancing the resilience of vulnerable communities through asset creation and capacity building at national and community levels. A core component of WFP's strategy to address climate change is working with partners to improve the knowledge base building on its extensive food security and vulnerability analysis capacity.

Understanding the ways in which climate risks affect vulnerability and livelihoods is a key step towards identifying the regions and communities that should be prioritised as well as the appropriate mechanisms for intervention. This analysis does precisely that by exploring several key issues. It examines the historical relationships between climate and food security. It also analyses the ways in which livelihoods are affected by climate risks. Finally, it uses this information to identify priorities for interventions.

We hope that this report not only help advance the climate change and food security dialogue in Nepal, but also provide concrete inputs for adaptation planning to build resilience in the most vulnerable regions of the country.

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Executive Summary

Food security is highly sensitive to climate risks in Nepal. Recent climate-related events, such as the 2008 floods and the 2008/2009 winter drought, have highlighted the potential impact of climate on food production, access to markets, and income from agricultural activities. However, the ways in which livelihoods and specific 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 2010/2011 Nepal Living Standards Survey (NLSS-III); and (iii) a workshop with national stakeholders to validate the results and identify priority adaptation interventions.

The analysis highlights the following trends:

Climate: Inter-annual and inter-seasonal rainfall trends are highly variable across the country. Recent rainfall data show trends of increasing intensity in summer monsoon rainfall – particularly in the eastern parts of the country, and declining rainfall in the winter months – particularly in the Mid- and Far Western parts of the country. In addition, analyses suggest that there has been a shift in the timing of rainfall, leading to more erratic and unpredictable precipitation patterns.

Climate impacts on food production: Rainfall is one of the main climatic determinants of food production in Nepal. Wetter years are generally associated with higher food production. Rice – the main staple in the country – is especially sensitive to changes in rainfall, and almost 50% of the variability in rice production can be explained by variations in rainfall. Winter crops (wheat and barley), which account for a significant proportion of food in the country, particularly in the Mid- and Far Western regions, are also highly dependent on sufficient rainfall during the winter months.

Climate impacts on food access: Access to markets is critical for food security in Nepal. This is especially the case in the mountain areas, where households depend heavily on markets and in-kind contributions during the agricultural lean seasons, despite limited market access and infrastructure. If winter precipitation continues to decline, food access could be affected in two inter-related ways. First, reduced winter crop production due to lower post-monsoon precipitation would force households to purchase more of their food. Second, climate-induced food price volatility could require households to spend more of their income on food. In addition, climate-related disasters limit physical access to markets.

Climate impacts on livelihoods: Food insecurity, particularly in the most vulnerable areas in Mid- and Far western Nepal, is 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 the adverse impacts of climate on food security in Nepal should therefore prioritise these regions.

To conclude, the report identifies seven areas of intervention to enhance food security and climate adaptation outcomes:

• **Adaptation to drought resulting from reduced *winter* rainfall through water management.** The Mid- and Far Western development regions of Nepal are the most vulnerable to the negative impacts of more erratic rainfall and declines in winter precipitation. Water management strategies, supported by 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 market stabilisation 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 access markets. Other innovative mechanisms such as insurance schemes can also help reduce some of the negative effects of climate on food security.

• **Asset creation and disaster risk management.** At the community level, conditional asset transfers including through food/cash-for-work interventions such as slope stabilisation, 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 rain-fed agriculture, strategies for livelihood and income diversification are critical to ensuring resilience. Support to migration (both seasonal and permanent) and additional income sources, such as wage labour, skilled non-farm activities and forest management can help improve livelihoods.

• **Capacity building at government and community levels.** Efforts to reduce climate impacts should also incorporate a strong capacity building and resource mobilisation component at government and community levels through awareness raising campaigns, as well as 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 this type of uncertainties, multiple risks need to be considered simultaneously.

Part I: Introduction and Context

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) The analysis aims to identify spatial *and* temporal relationships between food security and climate variables. In order to do so, long-term data series of food security indicators (crop yields, food prices, livestock product output) and climate parameters (precipitation and temperature) were correlated at the national and sub-national scales. (2) The second objective of the analysis is to establish a vulnerability baseline to assess the factors that render a household vulnerable to climate variability. (3) The final objective of this study is 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 (CBS, 2012). The topography of Nepal is very complex[†], 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 4,000 metres, and the mountain region towards the north of the country which includes areas at an altitude higher than 4,000 metres. These three zones run from east to west (Figure 1.1).

Further, Nepal is 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 1.1).

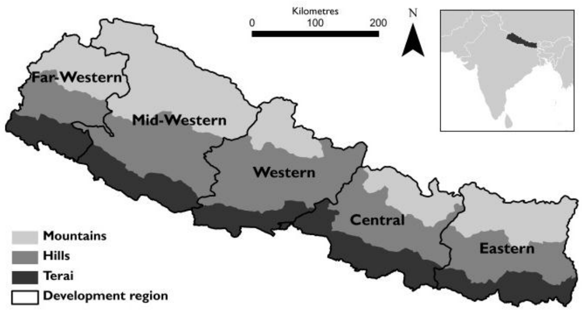


Figure 1.1. Ecological belts and development regions of Nepal

The map shows the three ecological belts (Terai, hills, and mountains) as well as the five development regions of Nepal. Each development region contains the three main physiographic features of Nepal.

Source: CBS (2011)

The distribution of population is uneven across the country: urban areas, particularly 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 this environment tends to be sensitive and less productive (Figure 1.2).

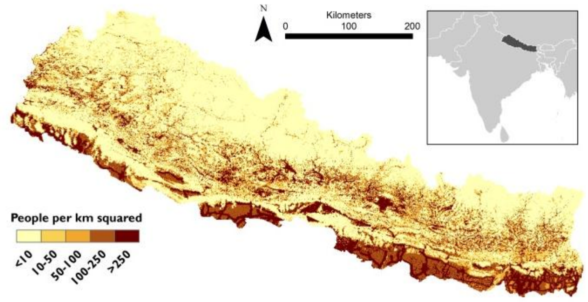


Figure 1.2. Population density in Nepal, 2010/2011

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.

Source: LandScan (2011)

[†] The varied topography of Nepal adds a layer of complexity to any vulnerability analysis.

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 (cf. Figure 1.3).

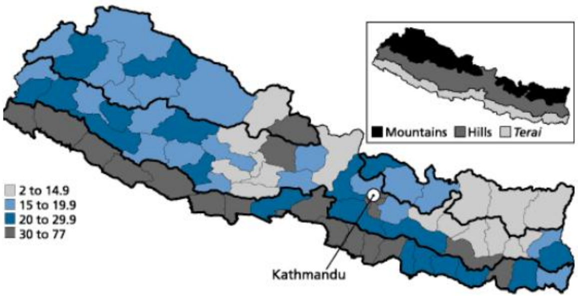


Figure 1.3. Population growth in Nepal, 2001-2011

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

Source: CBS (2011)

Poverty incidence at sub-regional level

Poverty remains a predominantly rural phenomenon: in 2010/2011 almost 28 per cent of the population in **rural** areas were poor whereas 15 per cent of the **urban** population were poor. The Eastern, Central and Western regions have a poverty incidence level below the national average whereas the Mid- and Far Western regions have poverty rates above the national average. The Terai is the region with the lowest incidence of poverty (23 per cent compared to 42 per cent in the mountains and 24 per cent in the hills). Incidence of poverty varies significantly across the country, ranging from 8.7 per cent in the urban hills to 42.3 per cent in the mountains (Figure 2).

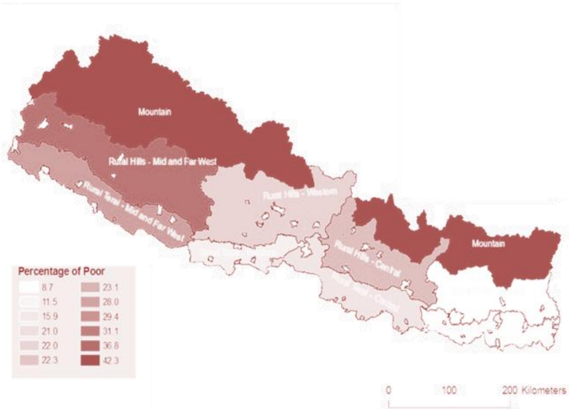


Figure 2. Poverty incidence at sub-regional level, 2006

The map highlights the incidence of poverty (proportion of the population that is considered to be below the poverty line) at sub-regional level. The results show 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 region.

Source: CBS (2011)

Significant progress has been made to reduce poverty in Nepal. According to the Central Bureau of Statistics (CBS, 2005; 2012) national poverty levels declined from 42 per cent in 1995/1996 to 31 per cent in 2003/2004 and further to 25 per cent in 2010/2011. The most significant progress was made in urban areas (excluding Kathmandu), where poverty levels declined by over 60 per cent. Poverty incidence decreased in the rural Eastern Terai by 33 per cent, in the rural Western hills by 32 per cent, in Kathmandu by 23 per cent, and in the rural Western Terai by 17 per cent.

Other measures of poverty, such as the Human Poverty Index (HPI) which measures life expectancy, access to basic education, and access to public and private resources, highlight that despite significant progress, the Western regions of Nepal remain deprived and are therefore less able to cope with food security and climate-related shocks (Figure 3).

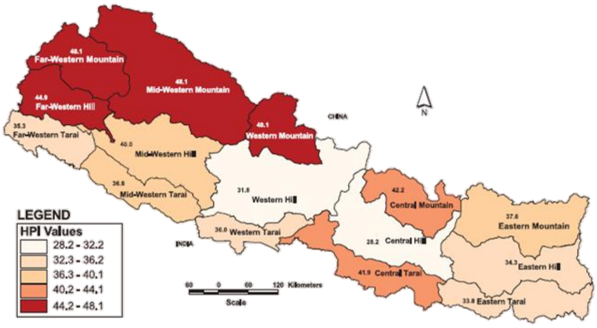


Figure 3. Human poverty index across eco-development regions of Nepal, 2006

The human poverty index (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 the government policies of balanced regional development, the regions most deprived in the past remain deprived today.

Source: UNDP, 2009a

Food security context

Despite significant development improvements in recent years, Nepal is a highly food insecure country: estimates suggest that approximately 38 per cent of the country's population is energy deficient (NPC and CBS, 2013). Nepal is influenced by the summer monsoon, and agriculture is predominantly rain-fed 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 Nepal. 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 per cent of their income on food (WFP and 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 (FAO/WFP, 2010; NPC and CBS, 2013; Figure 4). Social and human development indicators, such as life expectancy, and infant and maternal mortality rates have improved considerably in the same time (UNDP, 2010). The NLSS datasets 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.

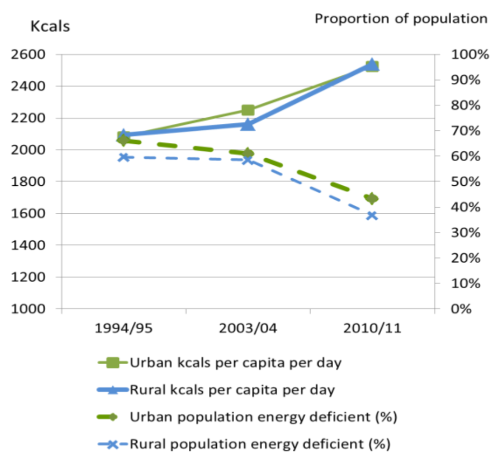


Figure 4. Food security trends in Nepal, 1994-2011.

The graphs show the trend in the proportion of people that are energy-deficient (in terms of caloric intake) in urban (blue) and rural areas (red). Between 2003/04 and 2010/11 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

Source: 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 5). 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.

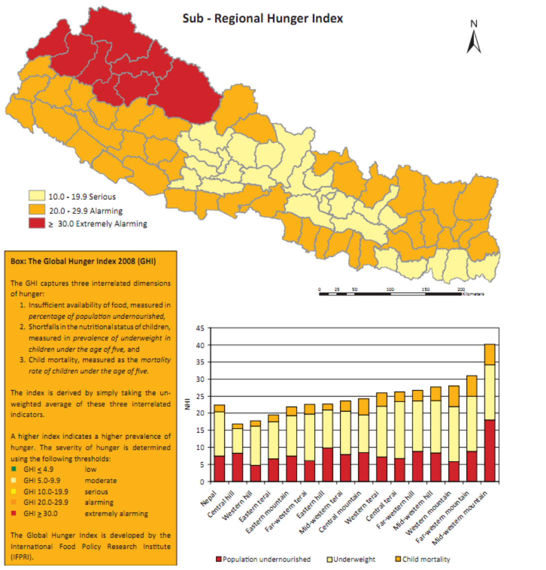


Figure 5. Sub-regional hunger rates in Nepal, 2008

The map shows the hunger rates in the different regions of Nepal using IFPRI's global hunger index. The results show that the most vulnerable and food insecure communities live in the Western Himalayan region of Nepal.

The Global Hunger Index is calculated by combining three factors: (i) proportion of population undernourished, (ii) prevalence of underweight in children under the age of 5, and (iii) mortality rate in children under 5. A higher index score indicates higher hunger risk (IFPRI, 2008).

Sources: WFP and NDRI, 2010

Climate trends

Weather station data indicate an increase in temperature trends across Nepal in the period 1975-2009 (DHM, 2010; McSweeney *et al*., 2010; Figure 6). 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).

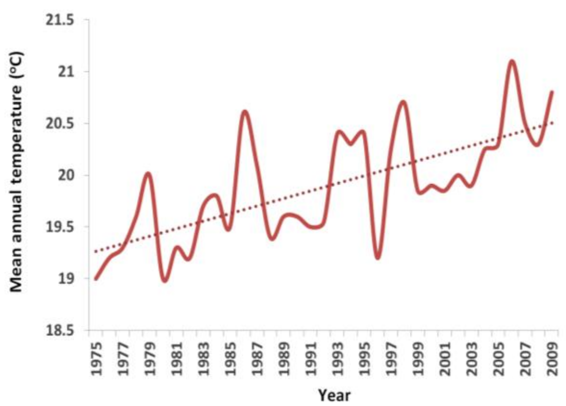


Figure 6. Mean temperature trends in Nepal (average from weather stations in the whole country), 1975-2005

Overall temperatures have increased by around 1.5 degrees Celsius 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 through March), especially in* ***the Himalayan regions, where average temperature has increased by 2 ºC since 1970.***

Source: McSweeney et al., 2010; DHM, 2010

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 7.1). 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; MoE, 2010). In spite of the difficulty to identify trends through weather station data, communities in the Himalayan and hill regions have observed a change in the form 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).

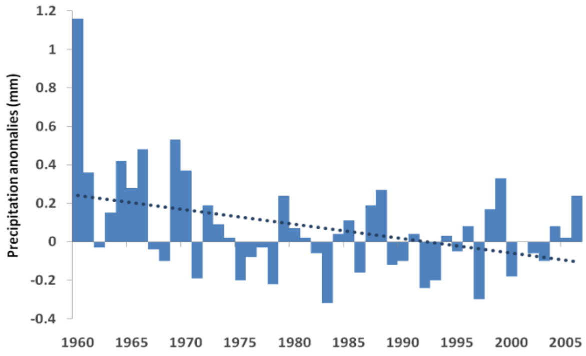


Figure 7.1. Precipitation anomaly trends in Nepal (average of the whole country), 1960-2005

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

Source: McSweeney et al., 2010

Climatology in Nepal is largely influenced by the complex topography of the Himalayan mountain range. The main rainy season is during the monsoon (June-September). Monsoon rain is most abundant in the eastern and central parts of the Nepal, and gradually declines as it moves westwards (Figure 7.2). The driest part of the country includes the mountain areas of the western regions, coinciding with the highest food insecurity rates.

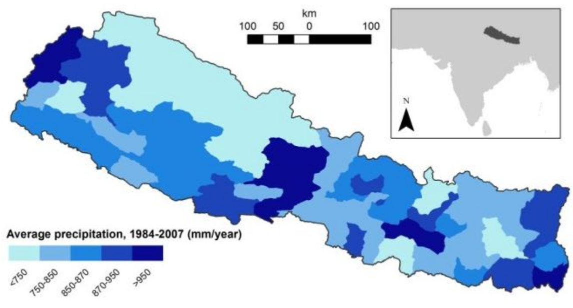


Figure 7.2. Rainfall climatology in Nepal: average annual precipitation in the period of 1984-2007.

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

Source: APHRODITE (2007), DHM (2010)

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).

Figure 7.3. 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

Results from weather station data for the period 1976-2005 indicate high rainfall variability across regions: whereas the western regions have experienced a decrease 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 7.3). 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 the Office for Coordination of Humanitarian Affairs' (OCHA) ReliefWeb suggest that, over the last 25 years, the impacts of floods occurring during the monsoon months (normally between June and August) have increased (Figure 8). 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).

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 more increasingly common with adverse impacts on populations.

Source: ISET-Nepal (2009)

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).

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

The historical record suggests no discernible trend in drought frequency (Figure 8). However, the winter drought of 2008/2009 was one of the worst on record and affected over 2 million people (MoAC et al., 2009; Photograph 2). As a result of the drought, over 40 districts were food-deficient (in terms of food-sufficiency of own production) compared to 30 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).

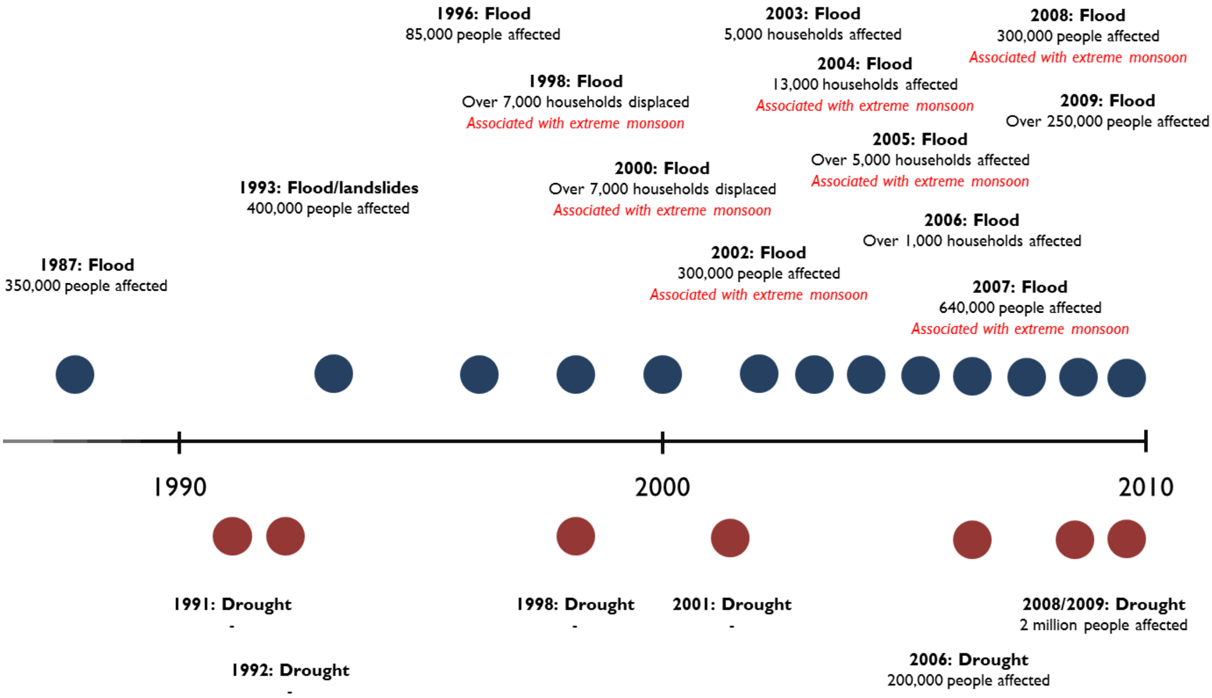


Figure 8. Flood and drought frequency between 1987 and 2010. The diagram shows the frequency of floods and droughts, as well as the number of affected people reported in OCHA's ReliefWeb, the Nepal Red Cross Society, and WFP. The diagram also highlights those floods associated with anomalous monsoons. 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. ***[Various sources]***

Photograph 2. The 2008/2009 drought was one of the worst in record, affecting over 2 million people. 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 9). 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 regions.

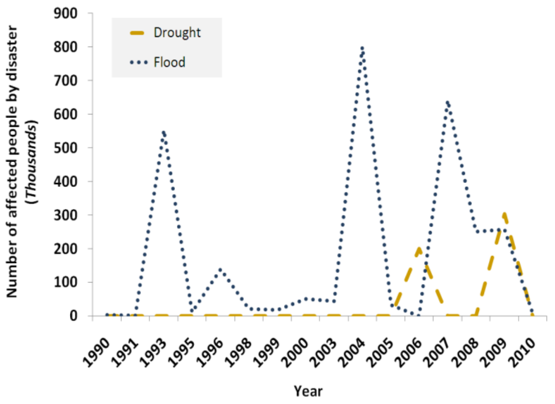


Figure 9. Number of people affected by climate-related disasters, 1990-2010

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).

Sources: 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 per cent 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 per cent for chickpea and lentils, and 28 per cent for potato (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 (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 snow fall. 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 they are timely.

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 degrees Centigrade by 2030 (+/- 0.3°C) compared to the 2000 baseline while regional models project a temperature increase of 1.4 degrees (+/- 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 region (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 per cent annual rainfall in eastern Nepal. The majority of this increase is due to more intense monsoon precipitation, resulting in up to 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 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 livelihoods 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 livestock raising in the mountain and hill regions, accelerated melt could lead to negative impacts on food security and livelihoods. Moreover, 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; 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 Lake, fed by the Tradkarding glacier which is retreating at a rate of 20 metres a year (UNEP, 2002). Due to melting of the glacier, the lake has grown six-fold (from an area of 0.23 square kilometres in the late 1950s to 1.5 square kilometres at present). This development poses a high risk to people downstream in the village of Tribeni: as 30 million cubic metres 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 US$ 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 generalise 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[‡] (WFP, 2010). This is because rain-fed 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 (also Figure 8). Acknowledging these relationships, this analysis highlights potential linkages between climate and food security at the regional level where possible[§].

[‡] The same monsoon outcome would affect crop production in Nepal as well.

[§] A regional analysis of climate trends is 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.

Part II: 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 between June and September. Approximately 80 per cent of the annual rainfall occurs during this period, and covers most of the country excluding the northern Himalayan region. The Mid- and Far-Western regions get less rain the Western, Central, and Eastern regions.

2. Westerly winds bring occasional rain in winter and early spring to the Mid- and Far-Western development regions.

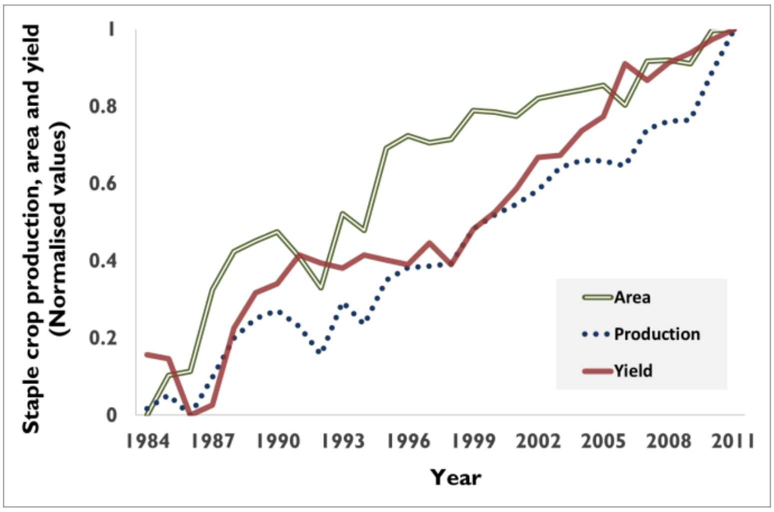
3. During the pre-monsoon months (March to May), local rains may occur over the hills and Terai — largely as thundershowers. These relatively unpredictable rains affect the agricultural cycle when they result in floods or landslides.

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 regions, the primary crops (wheat and barley) are grown between December and February when the winter rains occur.

Crop production trends

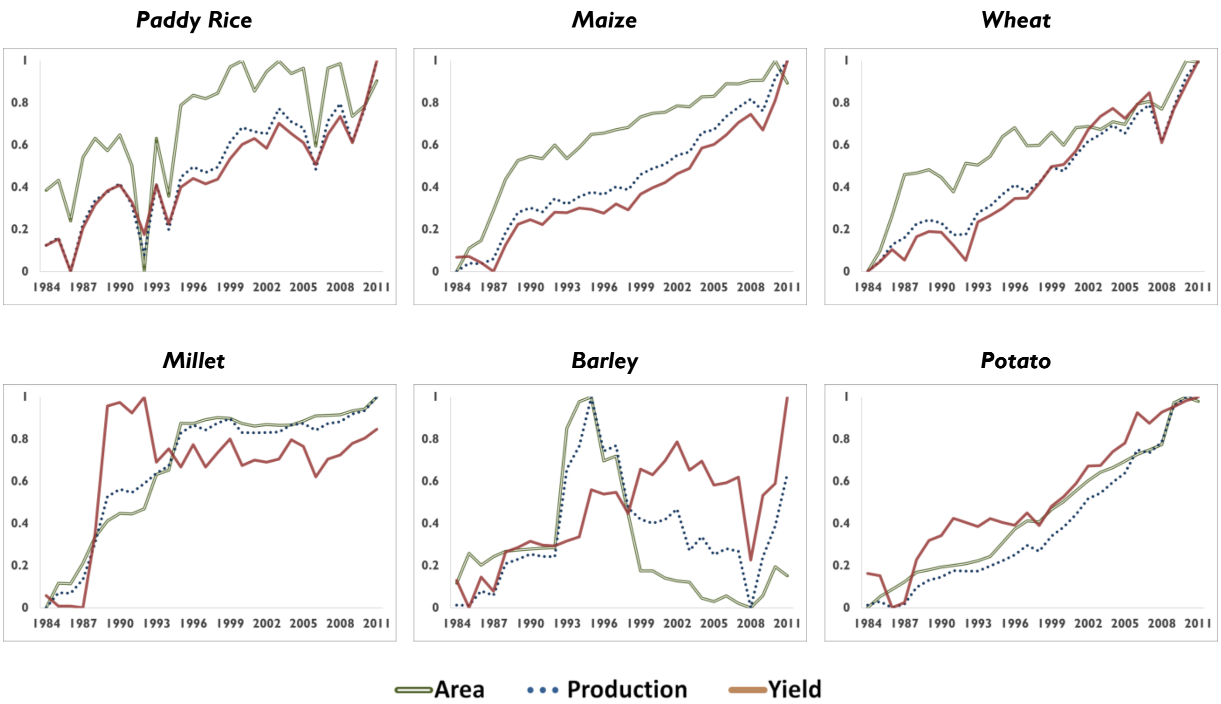
Agricultural production, yield and area harvested for the six most common crops in Nepal (paddy rice, maize, millet, wheat, barley and potato) increased steadily since 1984 (Figure 10; Ministry of Agriculture and Cooperatives, 2010). Increase in production up to the 1990s occurred largely due to area expansion, rather than due to increases in yields—this is particularly true in the case of maize and wheat (Paudyal, 2001; NARC, 2007; also Figure 10.1). In the period 1996-2008, however, productivity has increased more rapidly than area under cultivation.

Figure 10. Crop trends in Nepal, 1984-2011.



Production trends for the main crops in Nepal show a relatively stable increase in area cultivated, production and yields except in the context of barley and millet. Millet yields have been relatively stable after reaching a peak in 1999 with 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 which have forced farmers to identify alternative crops (Regmi, 2007). On the other hand, barley is considered a minor crop, so farmers have diversified into other crops as soon as alternatives become viable (WFP and NDRI, 2010).

Figure 10.1. Normalised 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.



Climate-yield relationship

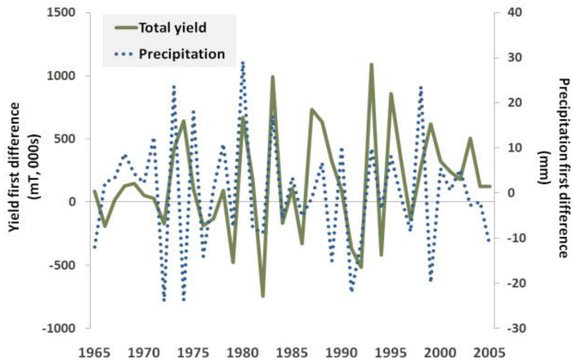
Quantifying the relationship between crop yields and climate is difficult. Given the importance of non-climatic variables including, among others, sub-national differences in farm inputs such as choice of fertilisers, irrigation techniques and seeds, as well as economic changes influencing agricultural management techniques are also very important. The results of the 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 11). Using year-to-year differences in time for climate and crop production (i.e. 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).

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 11.Precipitation and yield correlations, 1975-2005.



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 seasonal precipitation average during the main growth season were evaluated (cf. Joshi *et al.*, 2011).

The explanatory power of seasonal precipitation is higher for winter crops (close to 50 per cent) than for summer crops (close to 30 per cent) 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 Nino 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 likelier 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 if it is timely. However, rainfall is limited in the winter and therefore winter crops are highly sensitive to small changes in rainfall patterns.

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. WFP/James Giambrone.

Table 1. Correlation between crops and growing season precipitation

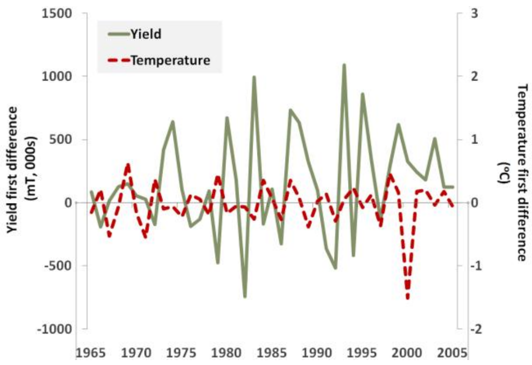
Crop	Correlation
Wheat (winter crop)	**0.533**
Barley (winter crop)	**0.495**
Paddy (summer crop)	**0.460**
Maize (summer crop)	**0.357**
Millet (summer crop)	0.349
Summer potatoes (summer crop)	0.292

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

Temperature

Variability in temperature has a low explanatory value with respect to yields than precipitation (R=-0.097, p=0.151; Figure 12). 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 Oosteromet *al*., 1995; Crafts-Brandner and Salvucci, 2002; Barnabas *et al*., 2007).

Figure 12.Temperature and yield correlations, 1975-2005.



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 (between 10 and 20 per cent 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 temperatures 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 2. Correlation between crops and growing season temperature

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 are considered[**]. A correlation analysis suggests that the variability of food commodity prices is more closely correlated with climate variables for

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

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.

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

Climate-price relationship

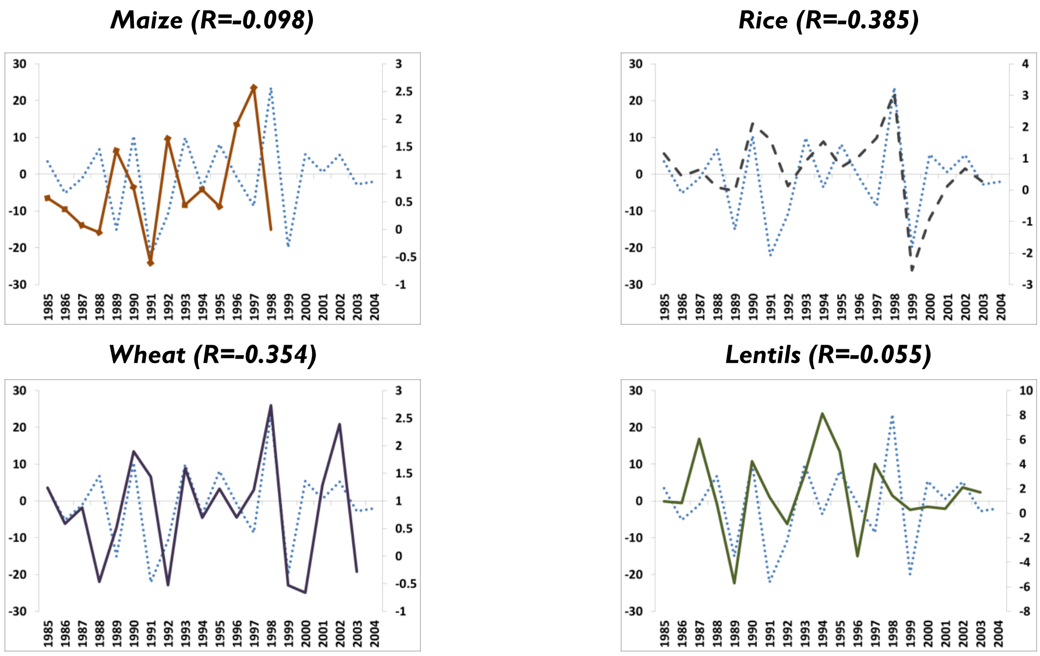
Food commodity prices for rice, maize, wheat and pulses were examined in relation to precipitation and temperature. The results indicate that food prices are generally negatively correlated with precipitation and positively correlated with temperature. Establishing relationships between climate variables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

The relatively low correlations between climate variables and food commodity prices, compared to yields, corroborate 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 13). 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 13. 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.

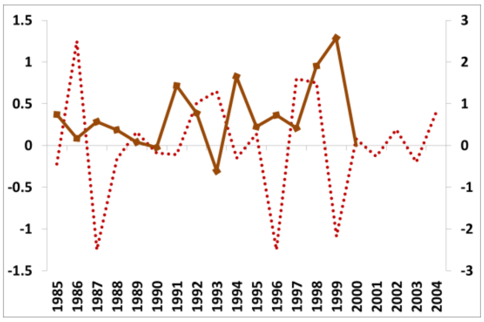


Temperature-price correlation

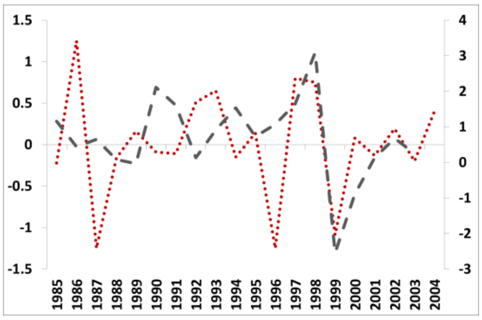
Food prices are positively correlated with non-detrended temperature (Figure 14). These results indicate that food prices are highest in warmer years, corroborating the findings of previous studies (cf. Thorton *et al.*, 2011). While it is difficult to ascertain how significant this difference is, the 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.

Figure 14. 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.

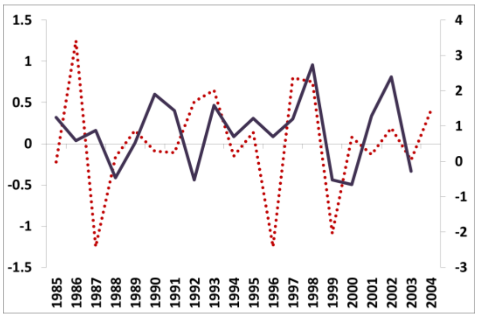
Maize (R=0.173)



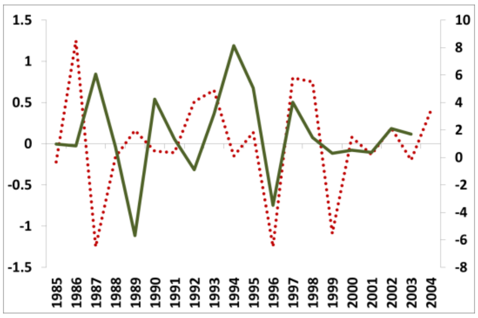
Rice (R=0.166)



Wheat (R=0.101)



Pulses (R=0.065)



Global analyses have identified relationships between climate trends and food prices (e.g. 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 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.

Livestock products have a strong correlation with climate variables (Figure 15). In particular, precipitation trends explain over 30% of inter-annual variability in 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, simultaneously with a large decline in precipitation which was in turn driven by a multi-year El Niño Southern Oscillation event (Shrestha *et al.*, 2000).

Figure 15.First-difference trends in precipitation (blue; right axis) and milk, meat, eggs and wool (dotted lines, left axis), 1985-2003. Correlations shown in brackets

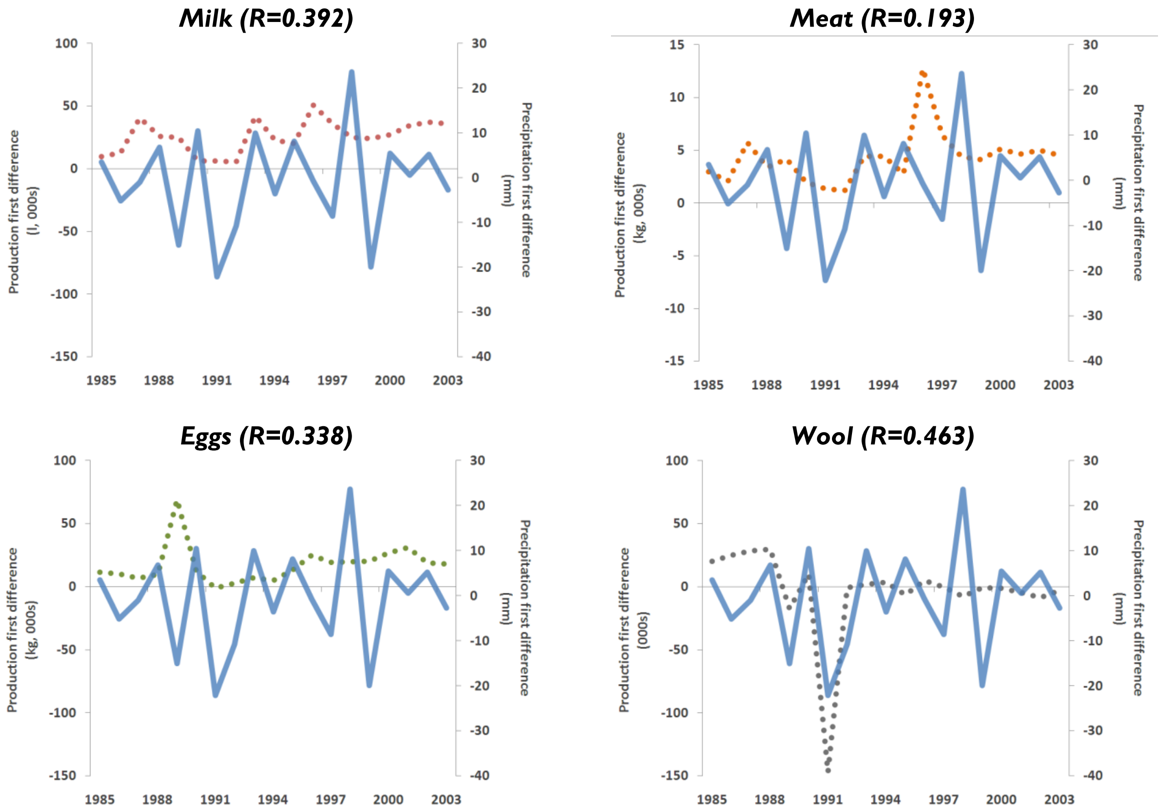


Table 4. Correlations between livestock products and temperature (1985-2003).

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 which 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 forgoing 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 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 grow livestock, and more specifically sheep, in the mountain regions – indeed the number of sheep declined in 1989/1990 (FAO, 2005). In addition, livestock situation in a number of districts in northern Nepal also depends on the 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 per cent 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 NRs 35,000."* 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 between 4,350 and 5,210 Nepali rupees. 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 landscapes and adaptation options.

Source: WFP and NDRI (2009)

Part III: 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 III (2010/2011). This is 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 Central Bureau of Statistics of Nepal[††].

Food security situation

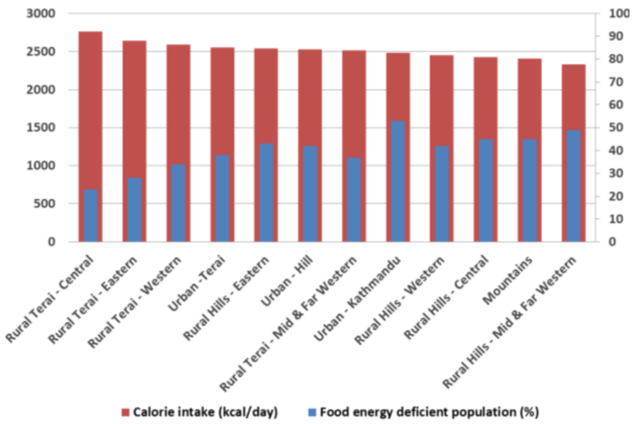
Main indicators: • calorie intake, • diet quality, • food consumption, • seasonality food consumption.

There is no single measure for food security. Indicators for diet quantity (caloric intake), diet quality (diversity) and 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 consume 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 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 16).

Figure 16. Diet quantity by region: calorie intake and proportion of population consuming less than the minimum caloric threshold.



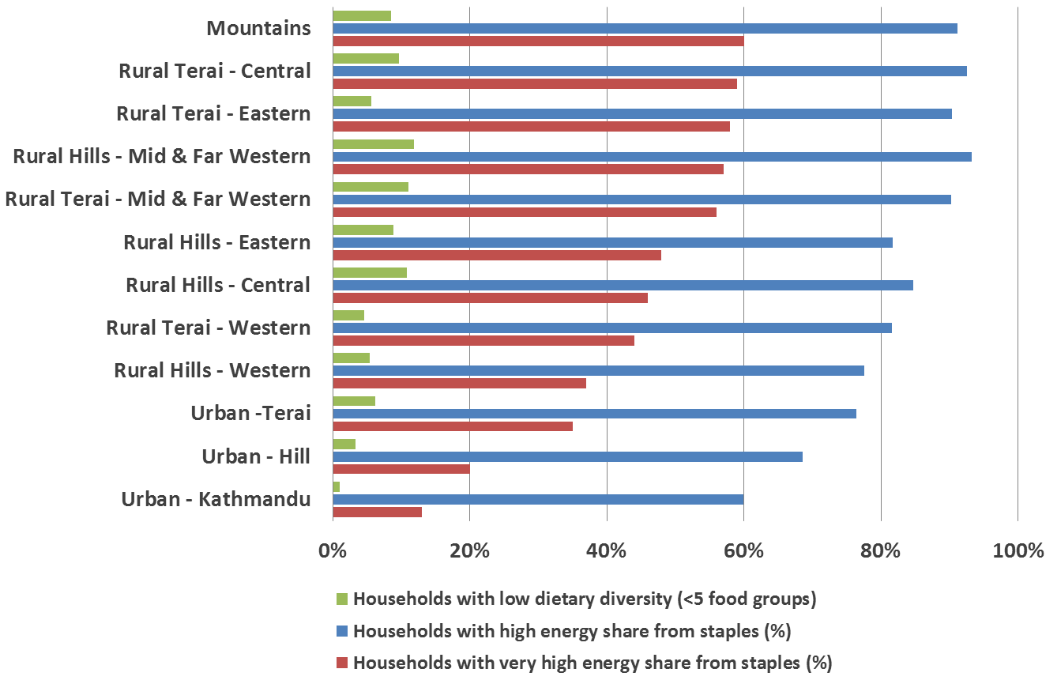
[††] Twelve analytical domains are used for this analysis: mountains, rural hills – Eastern, rural hills – Central, rural hills - Western, rural hills – Mid and Far Western, rural Terai – Eastern, rural Terai – Central, rural Terai – Western, rural Terai – Mid and Far Western, urban – Kathmandu valley, urban – hills, urban – Terai. Each of these analytical domains contains approximately 30 – 35 clusters of households, located in different districts, allowing for a generalisation 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**.

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, however only 19% of the urban population has a very high staple diet, highlighting the critical importance of staples in rural areas.

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)[‡‡]. 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 17).

Figure 17. 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).



Adequacy of food consumption

Adequacy of food consumption can be determined through the food consumption score (FCS)[§§] 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 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

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

[§§] 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.

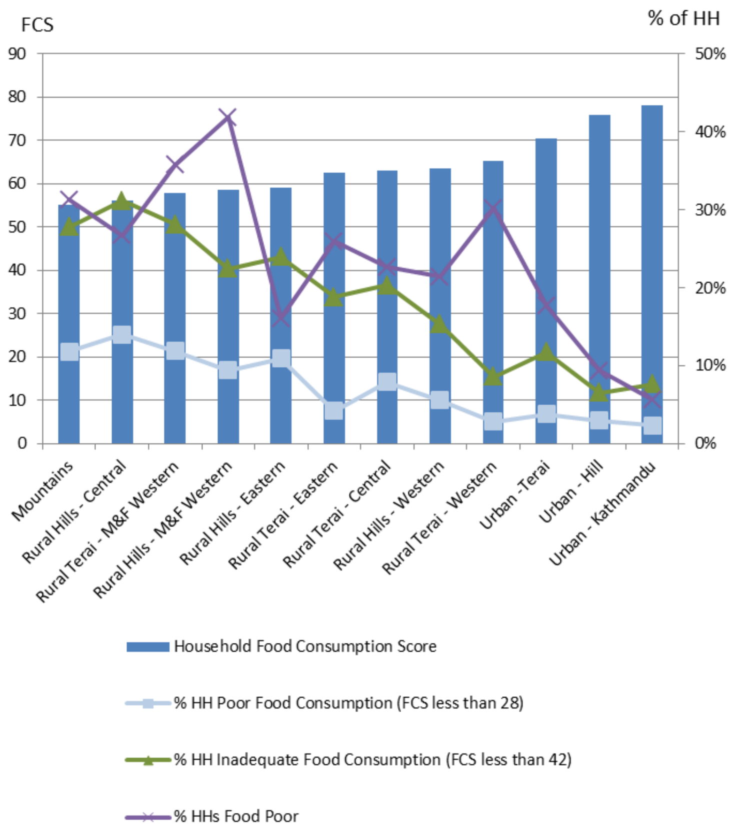
food prices. Both techniques include measures of diet 'quantity' and 'quality' – but FCS focuses more heavily on dietary diversity, whereas food poverty focuses on the overall quantity of consumption. The measures are complementary and should be analysed together to identify food security patterns.

Based on the FCS, the average household's food consumption in both rural and urban areas of Nepal is considered to be adequate (above the 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* (a FCS below 28). At a 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; in rural areas, 22% of the population consume an *inadequate diet and 28%* are considered *food poor*, compared to 9% with an *inadequate diet* in urban areas and 12% *food poor*.

While the FCS and food poverty measure 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, and the Mid and Far Western Hills and Terai (Figure 18).

Figure 18. Regional food consumption scores and percentage of households with inadequate consumption.



Seasonality of consumption

Analysis of average monthly consumption trends provides enhanced understanding of seasonal vulnerability to food insecurity. Seasonal vulnerability is important to understand: if households cannot even-out their consumption across the year then this highlights a pattern of chronic food insecurity – where households constantly slip in and out of hunger based on their own production cycles. It also provides important insight into when households need assistance the most. By analyzing patterns in kilocalorie consumption during 2010/11, it is possible to understand during which months households were most energy deprived and vulnerable to hunger. Analysis of the sources of food consumed provides a basic understanding of how households maintained their food consumption during the year through a mix of 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, March and April). Specific analysis was undertaken to determine how food consumption changed during these periods and whether agriculture lean periods were also periods of heightened food insecurity. The below seasonal analysis has been divided by Hills, Mountain and Terai. There is significant variation by development regions even within these broad 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 is from **household production**: the average household consumes 53% from their own production, 40% from purchased food, and 7% in-kind. In 2010/11 consumption of household food production decreased significantly during agriculture lean periods. For instance, in September 2010 towards the end of the first agriculture lean period of the year, households consumed on average 760 kilocalories per day from their own production, compared to 1650 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 procured, it would appear that households were adhering to this pattern of consumption through necessity rather than for economic reasons.

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:

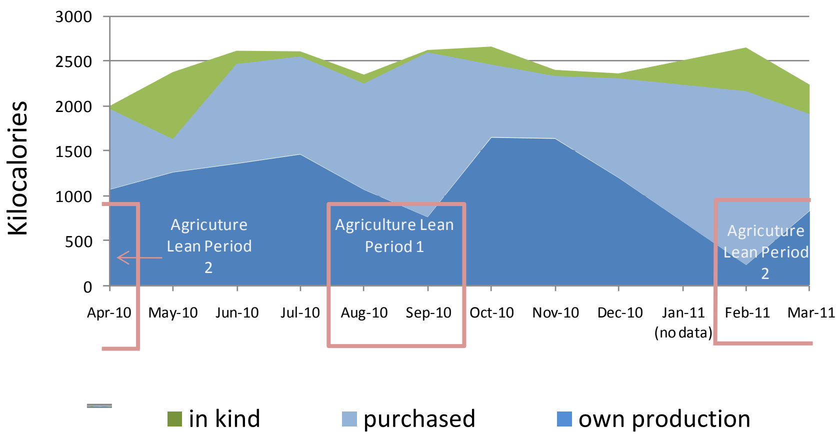
" These years there has been no snow fall in this village at all and each year the rain is coming less and less. Our village used to have enough food for an entire year. If there was drought the village would share. Now no household has food for more than three months – so the men must migrate to India.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

Source: WFP (2009)

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 is critical for maintaining a diet with adequate kilo-caloric 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, it can be seen that during the lean period in February 2011, that although consumption of own production was very low, households were sufficiently able to maintain adequate kilocalorie consumption through 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 agriculture lean periods, shows that consumption was significantly worse during the *February, March, April* lean season compared to other times of the year, across most indicators there was not a significant difference in consumption between the *August and September* lean period and the rest of the year.

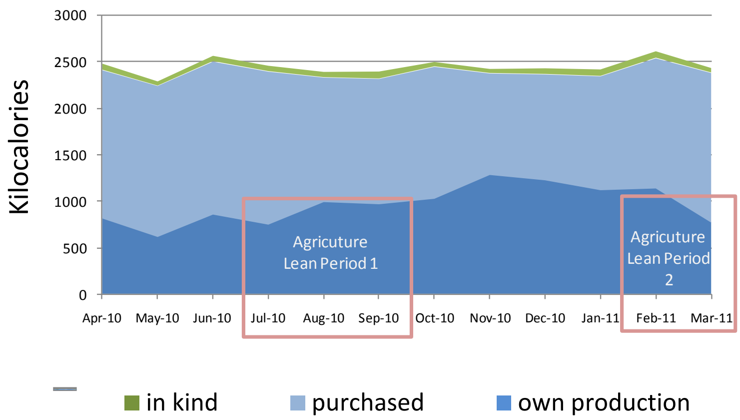
Figure 19.1. Mountain population, average monthly kilocalorie consumption by source



Rural Hills

In hill regions, the bulk of food consumed is **purchased**. The average household consumes 40% from their own production, 57% from purchased food, and 3% in-kind. Compared to households living in mountain areas, rural households in hill areas were generally better able to smooth the consumption of their own production throughout the year. There was more even consumption of household production and purchased food generally helped to even out overall consumption. However, it must be noted that insufficient data is available to analysis food source trends at a regional level and that there may be 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 agriculture lean period and 45% during the second period. This indicates that although households were able to smooth their overall kilocalorie consumption during the year, during agriculture lean periods they also had to rely on consuming less nutritious and less expensive foods.

Figure 19.2. Hill population, average monthly kilocalorie consumption by source.

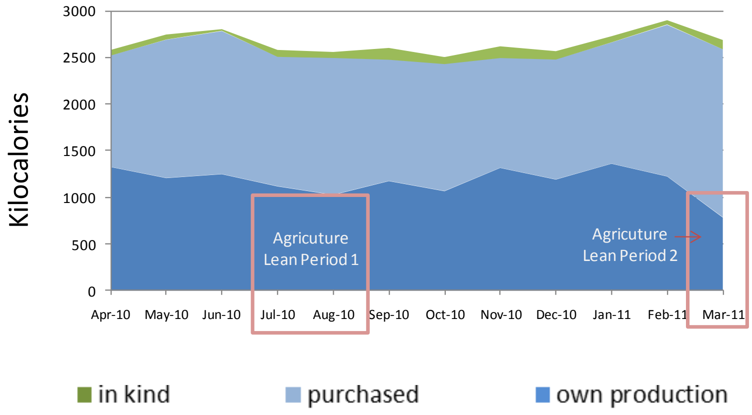


Rural Terai

In the Terai regions, the bulk of food consumed is **purchased**. The average household consumes 43% from their own production, 54% from purchased food, and 3% in-kind. In 2010/11 consumption of household production 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 energy deprived increases to 37%. Throughout the year, the average household is able to even out their consumption with purchased food, and when key food security indicators are considered, there were no overall fluctuations in food security correlating to agriculture lean periods. Therefore, it is likely that other issues, such as wage opportunities, individual household shocks, and the price of food –dictated by Indian prices- have a larger impact on food security than the seasonality of household production.

Under a climate change scenario, 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 19.3. Terai population, average monthly kilocalorie consumption by source



Food consumption and sources

Main indicators: • 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 Mid- and Far-Western regions. Finally, millet is consumed mostly in hill and mountain areas.

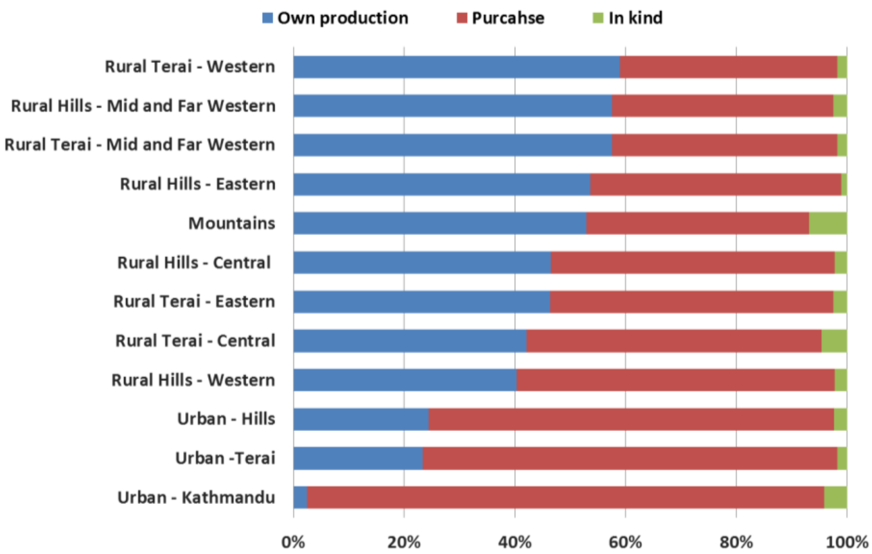
The main crop in Nepal—rice—is highly sensitive to changes in precipitation. As shown earlier in this report, historical climate trends indicate an increase in monsoon precipitation leading to higher rainfall in key producing areas of eastern Nepal. This trend is projected to continue under climate change but producing areas in western Nepal are likely to experience declines in rainfall which 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 own production or purchases. These two sources account for at least 80% of all food in all regions (Figure 20). Generally, in rural areas, there is a higher reliance on markets (especially for rice) in the mountain areas and in the Mid- and Far Western Zones—this is because households in the mountainous and Western parts of the country produce a deficit and 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 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. 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. Further, the increasingly erratic and untimely nature of rainfall makes it difficult for the farmers to plan sowing and planting in time, with potential adverse impacts on production.

Figure 20. Most common food sources and climate sensitivities (derived from NLSS-III)



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.**

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 very poor and poor wealth 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 per cent. Poverty and food insecurity in Nepal are highly linked to the dependence on markets.

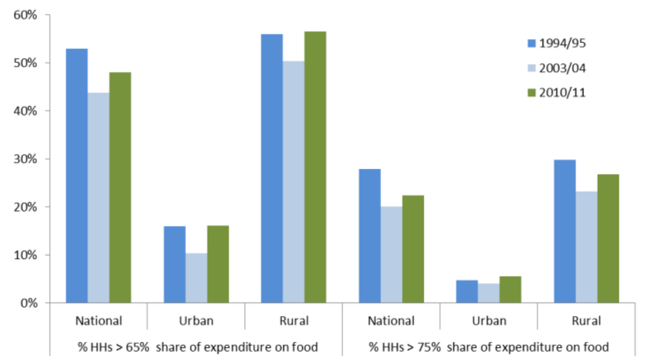
Despite significant increases in food prices, the food security situation in Nepal has been improving as highlighted in Part I. However, per cent of total expenditure on food remains very high in the hills and mountains, especially in the Far Western region of Nepal—over 40 per cent of households in this development region are unable to meet their food needs with their income and rely on various coping strategies such as seasonal migration and in-kind contributions during the agricultural lean season. Therefore, households in these areas are highly vulnerable to price shocks.

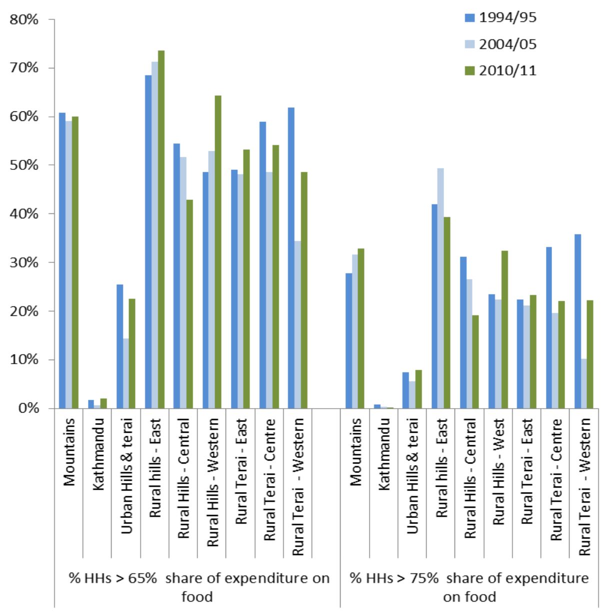
There is also a significant concern that, for the poorest and most disadvantaged, rapid food price inflation may have significantly exacerbated food insecurity. An analysis of the proportion of the population with high and very high food expenditure indicates that amongst some of the poorest households, food price increases has indeed increased economic vulnerability to food insecurity and has pushed a small proportion of households deeper into poverty (Figure 21).

While the average proportion of expenditure that the poorest households make on food has reduced since the 2003/04 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. With this level of expenditure on food, households living below or near the poverty line will not be able to cover their other essential needs. On the other hand, households living close to the poverty will not be able to invest in productive assets or other activities to improve their long term food security.

It is 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 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.

Figure 21. Food expenditure trends (derived from NLSS-I, II, and III)





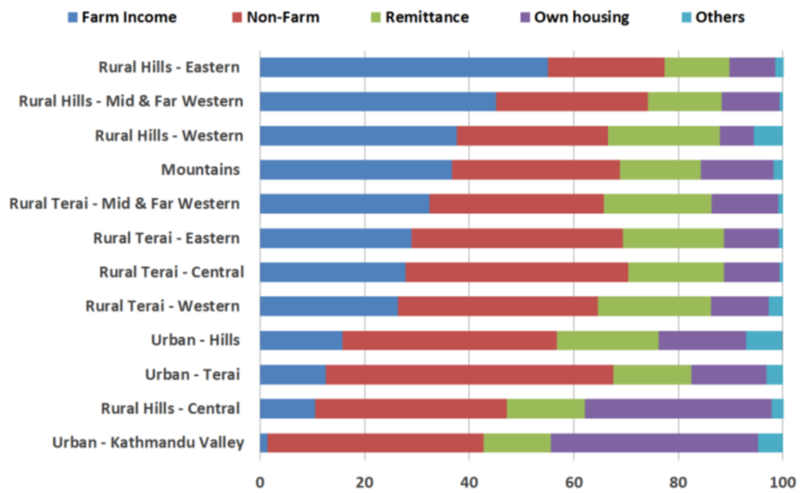
Under climate change, lower crop production (both from domestic production in Nepal and imports from India) could increase food prices. Additionally, more intense monsoons and landslides can complicate transportation of food to remote areas, thereby increasing both transport costs and food prices simultaneously.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

Income

Main indicators: • main source of income; • profession type; • wealth groups

Across Nepal, farming activities contribute more to income in the Far-Western development region and in Hill regions. Non-farm activities provide an important source of income in urban areas, particularly in the Terai. Remittances are important in all regions, although its contribution to total income is higher in western hills and in the Terai. Wealthier households are more likely to earn remittances from overseas and earn more per capita. Remittances also represent a greater percentage of overall household income in wealthier households. However, because poorer households spend more of their income on food, remittances play a particularly important role in the food security of the poor. Finally, consumption from own housing[***] and other activities such as renting out non-agricultural property like building or assets and earnings from savings/deposit accounts provide additional income to households, particularly in the Kathmandu valley and the central hills (Figure 22).

Figure 22. Income sources by region

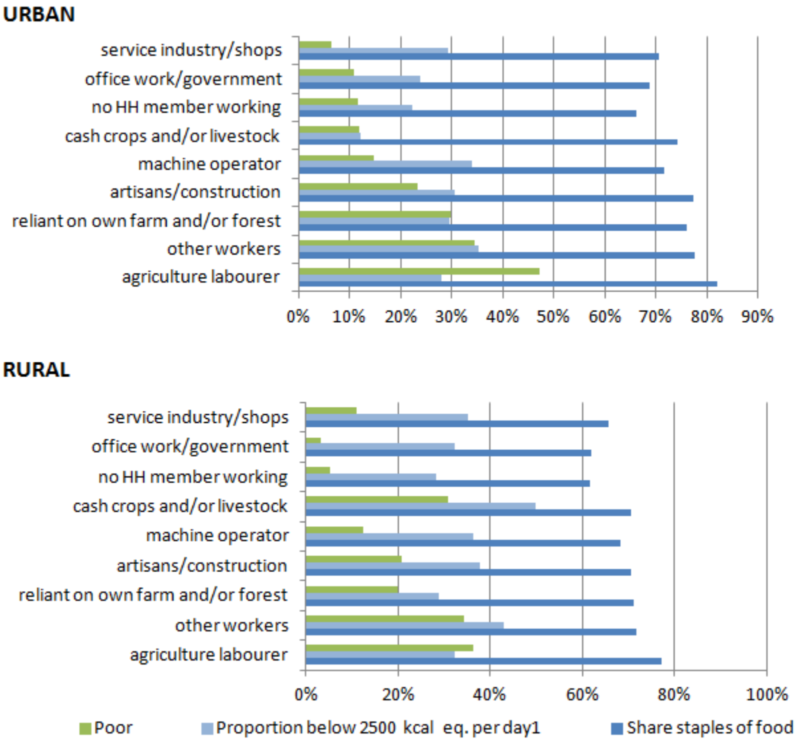


Farm income is particularly sensitive to climate variability. As highlighted earlier, crop production is linked to changes in precipitation, so erratic rainfall could result in unstable income sources. Farm activities are the most important source of income in the mountain and Western, Mid- and Far Western 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, 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 23). 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).

[***] Consumption from own housing refers to the income that the household would normally spend on rent but are saving due to occupancy of rent-free dwellings.

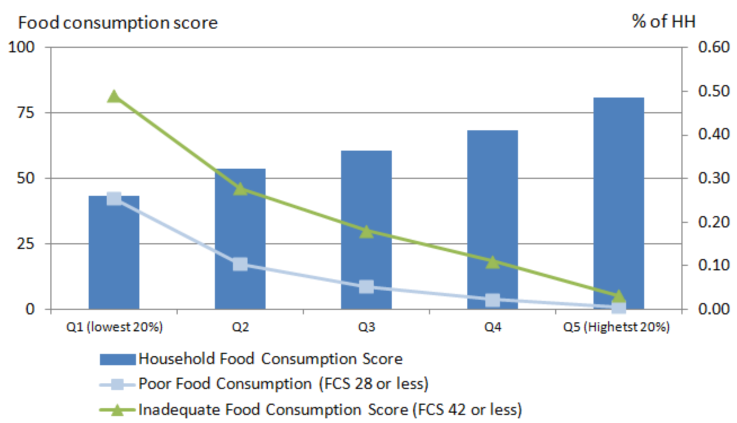
Figure 23. Food security, poverty and climate sensitivities by profession type



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.

There is a strong correlation between income and food security (Figure 24). 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 on the market.

Figure 24. Income by wealth quintiles and food security.



Part IV: 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) prioritises agriculture and food security as one of the most vulnerable to the adverse effects of climate change and variability. The NAPA prioritises 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 three of nine NAPA priorities include an explicit food security component, highlighting the urgency and immediacy of addressing climate risk in this sector. The NAPA recommends a combination of policies at different scales to reduce climate impacts. The analysis corroborates this 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 with 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, which 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.

How communities cope with climate risks

Communities manage risks associated with perceived climatic variability through a number of initiatives, especially crop failure which affects livelihoods and incomes.

Across the mountain regions of the country, one of the most common coping strategies is **crop substitution** (particularly to 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 dates, communities have reduced 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 season), from rural to urban areas (in search of non-agricultural wage jobs), and to other countries.

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

See also Pokharel and Byrne (2009)

Eight food security and adaptation considerations, based on consultations with experts from various national institutions[†††], 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 strategies. One such strategy might be supported through the installation of irrigation infrastructure and water optimisation 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.

[†††] A workshop was held with various organisations in December, 2011 to share the preliminary results of the analysis and to 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 organisations: ISET-Nepal (Institute for Social and Environmental Transition), the Department of Hydrology and Meteorology, the Ministry of Agriculture and Cooperatives, ICIMOD (the International Centre for Integrated Mountain Development), NDRI (Nepal Development Research Institute), Practical Action and IIDS (Institute for Integrated Development Studies).

• **Adaptation to floods and landslides resulting from erratic (and potentially more intense) *summer* rainfall through water management.** The analysis highlights that summer crops 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 which 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 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 stabilisation, 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 initiatives can help mitigate the negative effects of climate risk on food prices associated with higher transport costs. The monsoon limits food transportation in many areas of the country and private traders tend to adopt risk adverse strategies such as pre-monsoon commodity stock-piling which affect food prices. Traders opt not to re-stock during the monsoon period even when food stocks are depleted due to high transportation costs during these periods as this runs the 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 complicates 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 months (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 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 stabilisation 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, construction of disaster mitigation infrastructure such as embankments, dikes, and check dams, as well as construction of infrastructure to enhance access to facilities such as roads and mountain trails.

Photograph 4. Through terracing activities, communities in the Far-Western development region of Nepal are working to minimise disaster risk associated with floods and landslides. WFP/Deepesh Shrestha.

• **Support to 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 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 lead to improved livelihoods.

• **Capacity building at government and community levels.** Efforts to reduce climate impacts should also incorporate a strong capacity building and resource mobilisation component at government and community levels (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. For example, the Nepal Food Security Monitoring System (NeKSAP) – established by WFP in 2002, the system is currently being institutionalized within the Ministry of Agricultural Development under the strategic guidance of the National Planning Commission - 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, I/NGOs, UNs 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 available, 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.

Part V: 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. The 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 regions. Shifts in the timing of rainfall have also been recorded, suggesting more erratic and unpredictable rainfall.

The 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 selection of alternative crops (Gurung *et al.*, 2010), application of fertilisers (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 has been that of precipitation on crop production. 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 growing season, with winter crops being especially sensitive. Temperature also has an impact on food production although the impact 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 livestock production, 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 from areas that traditionally rely on livestock for their livelihoods.

A detailed analysis of livelihoods reveals that regional patterns of food insecurity, particularly in the most vulnerable areas in 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 prioritise 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 depend more on purchased food and on gifts 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 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 stabilisation 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 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/cash-for-work interventions such as slope stabilisation, 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 rain-fed 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.

• **Capacity building at government and community levels.** Efforts to reduce climate impacts should also incorporate a strong capacity building and resource mobilisation component at government and community levels through awareness raising campaigns, as well as 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

The food security adaptation recommendations identified through consultation with partners must be considered within the local contexts of vulnerability within the different regions of Nepal. The following table summarises the key climate and food security issues by analytical domain to better understand the context of vulnerability.

Mountains and Rural Hills

ANALYTICAL DOMAIN	GEOGRAPHICAL LOCATION	VULNERABILITY
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 lean season **Food source:** High reliance on domestic production throughout the year (~50%). Highest reliance in-kind contributions during the lean season **Main income source:** High reliance on both farm (~40%) and non-farm income (~30%) including non-timber forest products and remittances
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
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%)
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 Hills Mid & 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

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-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 **Food source:** High reliance on both markets (~50%) and domestic production (~40%) **Main income source:** Non-farm income (~40%), high reliance on remittances (~20%)
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-March) **Food source:** High reliance on domestic production (~60%) **Main income source:** Non-farm income (~40%), high reliance on remittances (~20%)
Rural Terai Mid & 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 (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 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%)
	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 I: 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 organisations 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 latter component of the method provides a forum for exchange of ideas and prioritisation 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 and to identify 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. The surveys are carried out by the Central Bureau of Statistics with technical support from other agencies including the World Bank and the United Nations World Food Programme (WFP). The data are obtained through household surveys. The aim of the survey is to track changes in the living standards of the Nepalese population since 1995/1996.

The survey follows the World Bank's Living Standards and Measurement Study (LSMS) method which uses standardised 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 interview also consists of panel 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. 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.

The Nepal Living Standards Survey III (2010/2011) provides a baseline of the living standards (including the food security situation) in Nepal under normal circumstances. Exploring the outputs of the NLSS - III 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 NLSS data (questionnaires, secondary data and livelihood profiles were examined). The relevant parameters from the 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 generalisation 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 which 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 on food sources informs about the impact of climate change on household consumption and corroborates the analysis of the income sources. These data are 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 retrieved 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 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 levels were obtained from a gauge-based analysis of daily precipitation collected under the APHRODITE project (Xie *et al*., 2007). Crop production, area, and yield data were obtained from the Ministry of Agriculture and Cooperatives (MoAC, 2009; 2010). Livestock product data were also collected from the Ministry of Agriculture and Cooperatives (MoAC, 2008). A summary of data collected and data sources is shown in Annex II.

Food security indicators were collected from the Ministry of Agriculture and Cooperatives (MoAC) Statistical Yearbooks (2008; 2009; 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 are collected and validated by various units under the Ministry of Agriculture and Cooperatives across the country, including the Nepal Agricultural Research Council as well as the Departments of Agriculture, Livestock Services, Cooperatives, Food Technology & Quality Control, and other related governmental as well as 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 are available on FAOSTAT (faostat.fao.org/). Data are collected through collaboration with national governments who provide statistics in the form of replies to regular Food and Agriculture Organisation's (FAO) questionnaires. Missing values, particularly in the early part of the record, are estimated based on a trend analysis. These data are the longest standardised 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 Regional Data Exchange Systems (FAO-RDES, 2006; faorap-apcas.org/nepal.html) which collects standardised agricultural and food security data through collaboration with the Central Bureau of Statistics (CBS). Agricultural data are 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 Central Bureau of Statistics 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 (ADB) and FAO. This dataset is particularly relevant to the purposes of this study as it allows for analysis of spatial relationships between food production and climate parameters.

Market price data for food items are collected fortnightly by the Agribusiness Promotion and Marketing Development Directorate (ABPMDD) of the Ministry of Agriculture and Cooperatives from 21 markets across Nepal.

Nutrition data—a descriptive component of food utilisation 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, http://www.measuredhs.com/). DHS data are 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; in order to evaluate relationships between climate parameters and nutrition impacts, longer time series would 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/) which have centralised and processed climate information from a number of datasets in a standardised manner. Temperature data were processed through re-analysis from the National Centres for Environmental Prediction (NCEP, http://www.ncep.noaa.gov/) data sets (cf. Kalnay *et al*., 1996). Gridded station precipitation data were processed from the University of Delaware climate datasets (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 provide a useful time series to examine climate-related trends across the country.

Daily precipitation data at the regional level were obtained from averaging station data collected under the Asian Precipitation – Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE; 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 Nepal—, 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 in all regions and ecological zones of Nepal. These data allow for analysis of climate and food security trends at district level and provide 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 correlations.

The purpose of this analysis is to identify vulnerability and food insecurity correlations with climatic factors. The results presented in this 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 which 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 (i.e. the differences in value from one year to the next). This method has been used in other studies to minimise the influence of gradual inter-annual changes associated with changes in crop management (e.g. 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 is 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 per cent ($p \leq 0.1$) 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. The 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 organisations

The aim of this component of the method was to engage key agencies to validate 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 Country Office in Nepal between December 5^{th} and December 8^{th}. Participants included members from various government agencies (including the National Planning Commission, the Department of Hydrology and Meteorology, and the Ministry of Agriculture and Cooperatives), as well as local experts from intergovernmental and non-governmental organisations such as the International Centre for Integrated Mountain Development (ICIMOD), Practical Action, CARE International and the Institute for Social and Environmental Transition (ISET) and the Nepal Development Research Institute (NDRI).

During the workshop, participants were asked to form groups to discuss (i) the validity of the results, (ii) additional analysis required, and (iii) adaptation implications of the analysis. Each group appointed one scribe to collect and present the discussion 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 II: 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° x 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 Nepal Living Standard Survey – III, 2010/2011 (CBS, 2011).

Annex III: 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.

1. 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 centralised and managed by the Department of Hydrology and Meteorology. Apart from a few publications which include long-term data from a handful of stations, the majority of data is not shared with the public. Accessing this information often involves purchasing yearly data for individual stations. The data used here were obtained through an on-going collaboration between WFP and the Government of Nepal to analyse food security in the country.

An additional challenge is 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 Central Bureau of Statistics and the Ministry of Agriculture and Cooperatives. These data have been distributed through publications and collaboration with international organisations such as FAO. The main challenge, however, is that long-term data do not exist for certain indicators.

Most time series data focus on production indicators which are easier to quantify. Other important information such as caloric requirements compared to caloric availability, or 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 dataset for nutrition statistics is the Demographic Household Surveys; however, the data are not available on a yearly basis. Additionally, climate impacts on nutrition could only be felt over the long run, so the impacts would be difficult to quantify.

2. 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 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 (GAUL) developed by FAO and used for WFP's planning purposes.

3. 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 and overall vulnerability trends.

Non-climatic factors need to be considered to accurately determine the conditions which 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.