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Climate Change Impacts and Adaptation in Nepal

Ryan Bartlett, Luna Bharati, Dhruba Pant, Heather Hosterman and Peter McCornick

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Contents

Acronyms and Abbreviations

ABC	Atmospheric Brown Clouds
CC	Climate change
DAO	District Administration Office
DDC	District Development Committee
DWRC	District Water Resources Committee
DWSS	Department of Water Sanitation and Supply
GCM	General Circulation Model
GLOF	Glacial Lake Outburst Floods
GDP	Gross Domestic Product
INGO	International Non-Governmental Organization
LDC	Least developed country
NAPA	National Adaptation Plan of Action
NGO	Non-governmental organization
NPC	National Planning Commission
NWP	National Water Plan
NWRDC	National Water Resources Development Council
RBO	River Basin Organization
UNFCCC	United Nations
VDC	Village Development Committee
WECS	Water and Energy Commission Secretariat

Summary

The impact of climate change (CC) on water resources is likely to affect agricultural systems and food security. This is especially critical in a least developed country (LDC) like Nepal where a high percentage of the population is dependent on agriculture for its livelihoods. It is, therefore, crucial for Nepal's leaders and resource managers to draft and begin implementing national adaptation plans. In order for such planning to be effective, it is critical to gain a more comprehensive understanding of the anticipated impacts of CC and the institutions potentially involved in the adaptation process. This working paper aims to create a more comprehensive understanding of how the impacts of CC will be realized at different scales in Nepal, from household livelihoods to national food security, and the many institutions governing the ultimate adaptation process. Recommendations for adaptation to be effective include a need for a comprehensive effort, involving integrated national planning across all sectors and new infrastructure development (e.g., irrigation, hydropower) to account for longer term impacts of CC. For autonomous adaptation, the focus must be on building and expanding basic infrastructure at the local level which will help provide greater income diversification and access to markets. Such infrastructure will also allow for greater interconnectedness between isolated communities, national government institutions and non-governmental organizations (NGOs). For many local communities, adaptation and development will thus be synonymous because as incomes become more diverse and livelihoods improve, so will resilience towards climate shocks. Fundamental failures of governance and institutional effectiveness must be overcome in order for basic development, and especially for effective strategic adaptation planning and implementation, to occur. Capacity building on CC impacts within the various government departments and ministries is advocated. Furthermore, developing water management strategies as well as agricultural diversification plans, which focus on the increasing variability and uncertainly in water supplies, is also seen as being critical.

INTRODUCTION

The impacts of CC in South Asia are beginning to be felt in a number of ways, but most critical are likely to be those impacts that are affecting water resources, which directly affect agricultural systems and food security. There is an abundant water supply in the region, but because it is so unequally distributed, both spatially and temporally, agricultural productivity is low, inconsistent and severely dependent on weather patterns. As anticipated changes to the timing of the monsoon and expected adverse effects of CC begin to be felt on a wider scale and in a variety of ways (including increasingly frequent disaster events, more extreme storms and prolonged droughts, and an increasingly variable water supply), massive pressures will be levied on ecosystems, from water bodies to forests and agricultural lands, further limiting agricultural productivity in the region. In addition to these climate factors, socioeconomic aspects like high levels of poverty, migration and increasing population growth will also place an even greater pressure on agricultural system capacity and productivity. What this means for a small LDC like Nepal, with such an extreme geography and a high percentage of the population being dependent on agriculture for livelihoods (NCVST 2009), is not well understood.

This working paper aims to create a more comprehensive understanding of how the impacts of CC will be realized at different scales in Nepal (from household livelihoods to national food security), and the many institutions governing the ultimate adaptation process. Section I, *Background*, provides background information on Nepal. Section II, *Climate Change in Nepal*, addresses the anticipated impacts of CC on water resources and agricultural systems in Nepal. Section III, *Mapping of Relevant Institutions for Climate Change Adaptation*, provides a theoretical discussion of adaptation and, through a case study analysis of the Koshi River Basin using institutional mapping to assess the various hierarchies of resource management and development in the basin, attempts to understand the institutional framework that will ultimately govern the adaptation process. Section IV, *Constraints to Adaptation*, describes the current constraints to adaptation. Finally, Section V, *Conclusions and Recommendations*, outlines recommendations for adaptation action for Nepal in the future, given the environmental and sociopolitical realities on the ground.

BACKGROUND

Social and Economic Conditions

Nepal is a LDC in South Asia, as reflected by a number of different criteria. We discuss below a few general indicators that are useful in understanding and providing at least a basic picture of the socioeconomic constraints that the country faces in ultimately dealing with the comprehensive effects of CC.

According to World Bank data (as of 2004), over 30% of the population lives below the international poverty line of US$1.25/day and gross national income (GNI) per capita is only US$1,100 purchasing power parity (PPP) (World Bank 2010). Unemployment is as high as 46%, ranking it 190 out of 200 countries, and the inflation rate is around 13% (208 out of 222 countries) (CIA 2010). Such high unemployment rates are, in part, the result of an economy in transition, where though nearly 70% of the population is dependent on agriculture for livelihoods in the formal economy, there is also considerable evidence that increasing percentages of household income come from nonagricultural sources and jobs in the informal economy that are more service based (NCVST 2009). Such a singular shift in the economy from one industry

to another is not surprising, given the lack of skilled workers, where the national literacy rate is just under 60%, of which the majority are men, with women only being 62% as literate as men (UNICEF 2010).

Health statistics paint a similar picture of lacking development. Life expectancy is one of the lowest in Asia at 63; almost 50,000 children die from curable diseases every year, with 60% of those dying due to malnutrition alone; 49 and 39% of children between 0 and 5 years have stunted growth and are underweight; and 75% of pregnant women are anemic (World Bank 2010; IRIN 2008b). Only 27% of Nepal's population has access to improved sanitation (World Bank 2010). Not surprisingly, as a result of the combination of these socioeconomic and health statistics, Nepal is ranked low in UNDP's Human Development Index (HDI), and is 142 out of 177 measured countries (Watkins 2008). One major contributor to such a low ranking is the weakened and underdeveloped state of the country's agricultural production and water resource infrastructure.

Water Resources

Nepal is one of the most water-abundant countries in the world with its 6,000 rivers, total mean annual runoff of 224 billion cubic meters (BCM) and per capita water availability of 9,000 cubic meters (m^3). Yet, the National Water Plan of Nepal (2005) indicates that only 72% of the population has access to safe drinking water, only 562 megawatts (MW) of hydropower capacity are exploited (out of an estimated economically feasible potential of 42,000 MW), and "little consideration is given to environmental requirements." Furthermore, nearly 70% of Nepal's population depends on subsistence agriculture for livelihoods (NCVST 2009). Agriculture consumes around 96% of all water withdrawn in the country (CIA 2010), which is a reflection of the limited development of the nonagricultural sectors rather than the dominance of agriculture. Only 24% of arable land is irrigated, crop productivity is significantly lower than in the rest of South Asia, and the country relies heavily on food imports from India.

The hydrology of Nepal is primarily monsoon-driven. Around 85% of rainfall occurs during the four monsoon months of June to September. The temporal variability of rainfall and runoff is hence very high, and the problem of excess water during the monsoon and water scarcity during the dry season affects all aspects of life in the country. During the 2008-2009 drought, there were power cuts lasting up to 16 hours per day in Kathmandu, barley and wheat crop yields dropped, and nearly 2 million people were food insecure (WFP 2009). Yet, in the same year, floods in the following monsoon destroyed significant areas of growing crops.

Agriculture

Agricultural production comprises 32% of Nepal's gross domestic product (GDP) (World Bank 2009b), but only 13% of that production is traded in markets (World Bank 2009a). Agricultural lands are primarily divided between three agroecological zones: the lowlands of the Terai (which comprise 43% of total cultivated land), the regions of the lower hills and mountains of the upper Himalayas (World Bank 2009a). Rice is the primary crop in the lower elevation regions of the country, wheat is grown in the Terai and the valleys of the Himalayas, and corn is the principle crop of the hilly regions (Stads and Shrestha 2008).

The mountains generally lie above 1,800 meters (m), of which only 2% of the land is suitable for cultivation. Since the mountain region is mostly steep, rugged and cold, it is sparsely populated with the main occupation of the people - raising livestock. Due to the country's extreme geography and abrupt topographical changes, only about 17% of Nepal's total land area is suitable for agriculture, compromising approximately 2.5 million hectares (Mha) with a cropping intensity varying from one to three crops per year, much of which is limited to terracing on high grade hillsides (which limits the cost-effectiveness and reach of man-made irrigation systems). It is, therefore, not surprising that 65% of arable land is rain-fed, with only 24% having access to irrigation systems (HMG 2001). Most of the irrigable land is the Terai. There is some irrigation in the middle hills and mountains, but it is primarily limited to small-scale surface irrigation and micro-irrigation, such as drip or limited sprinkler systems. Vegetables are cultivated as cash crops in a few areas in the mid-hills with access to markets. The vast majority of the mountains are, however, remote and access to markets and roads is limited.

Prior to 1980, Nepal was able to meet all of its domestic cereal needs, but as population growth has outpaced agricultural productivity, it has been forced to heavily rely on food imports, primarily from India and other countries in the region (HMG 2001). Crop productivity, at 20-30%, is significantly lower than that of the rest of South Asia. This can be attributed to a variety of factors. Most production is at subsistence levels and limited to smaller, nonindustrial operations. Farmer landholdings are extremely small, with less than 100,000 farmers owning more than 0.3 hectares (ha) of cropland and the vast majority farming on less than 0.5 ha (IRIN 2008a). Land degradation from unsustainable land use also severely limits crop productivity. Overgrazing, rampant deforestation, overuse of chemical fertilizers, and unscientific farming practices have all contributed to widespread topsoil erosion and nutrient loss, contributing to already naturally frequent occurrences of landslides in the hills and floods in the lowlands (Karkee 2004; Regmi 2008).

Political Situation

Perhaps most significantly impacting the agricultural sector and food security have been, and continue to be, the impacts from the decade-long armed conflict that created up to 200,000 internally displaced persons (IDPs) and devastated a highly agriculturally dependent economy (IRIN 2008b). The remnants of the armed conflict have made the situation almost as difficult today, as party politics have become endemic in all aspects of society and strikes from numerous ethnic groups affiliated with varying parties (there are more than 20 parties in the government and over 100 ethnic groups in Nepal) occur frequently. Such strikes, or "bandhs" (as they are referred to locally), shutdown roads and essentially grind the economy to a halt, preventing people from working, the transportation of goods, and further adversely affecting the severely poor by preventing the delivery of food aid (IRIN 2008c). Due to political reasons, but also resulting from environmental and economic pressures, there has been an increasing trend of male migration from rural areas to urban centers. Abandonment of farms results in land erosion on fragile unmaintained terraces, women and elderly heading farm households and remittance income being the backbone of livelihoods.

All of these factors, from unsustainable land use practices, poor existing water and irrigation infrastructure, to political upheaval, create a tenuous food security situation in the country. Adding the potential impacts of CC further complicates this already complex mix of environmental, political and socioeconomic pressures on a fragile and vulnerable Nepali agricultural system, and could easily lead to worsened food insecurity without significant changes to the status quo.

CLIMATE CHANGE IN NEPAL

General Overview

Peer-reviewed studies analyzing regional changes due to global CC in South Asia - and even more so in Nepal are limited, especially in relation to water resources, because of the difficulty in scaling down the general circulation models (GCMs), a lack of long-term climate records, and the natural high variability of water supply (Cruz et al. 2007; HMG 2005; Eriksson et al. 2009). Also, GCM outputs do not have sufficient spatial resolution to provide information on changes across the different elevation zones. A variety of different non-climate factors that have varying effects on water resources and agricultural systems in the region, including pervasive resource mismanagement and rapid population growth, also cloud the effects of CC. There are, however, general trends that have been corroborated by ground level observations of various communities in Nepal that do at least give a basic framework of the identified and projected changes, including glacial melt, changes in precipitation patterns, and increasing water stress into the twentieth century, with most of South Asia projected to be under water stress by 2050 (IPCC 2007; UNEP 2008; Bates et al. 2008). The following section summarizes information that is available in existing literature on the primary climate variables, i.e., temperature, precipitation and runoff for Nepal (IPCC 2007; World Bank 2009b; NCVST 2009; McSweeney et al. 2008; Bates et al. 2008; Kundzewicz et al. 2007). Table 1 below provides a brief outline of the likely changes to these variables.

Temperature

Some observed studies on climate trends suggest that from 1960-2003 there have been no increases in annual temperature over Nepal (World Bank 2009b; McSweeney et al. 2008). Other studies cite an increase in temperature in recent years (Cruz et al. 2007; Agrawala et al. 2003), with more pronounced warming at higher altitudes (Liu and Chen 2000; Bhutiyani et al. 2010). There has been a small but significant increase in the frequency of hot nights and a significant decline in the annual frequency of cold days and nights. Hot nights have increased by 2.5% (McSweeney et al. 2008). GCMs predict that the country is expected to become warmer with more frequent heat waves and less frost. Average temperature is predicted to rise significantly by 0.5 to 2.0 ºC by 2030 (NCVST 2009), 1.3 to 3.8 ºC by 2060, and by 1.8 to 5.8 ºC by 2090 (McSweeney et al. 2008). The number of days and nights considered hot by current climate standards is projected to increase, occurring on 11 to 18% of days and on 18 to 28% of nights by the 2060s. The greatest increase is projected to occur during the months of June to August (McSweeney et al. 2008).

Precipitation

Projected mean annual precipitation for Nepal does not show a clear trend with reference to both increases and decreases: -34 to +22% by the 2030s; -36 to +67% by the 2060s; and -43 to +80% by the 2090s (NCVST 2009). This is, in part, because the exact effects of CC on precipitation levels in the region are based on complex factors governing the Asian monsoon and their interaction with increased carbon dioxide (CO_2) levels, which is not well understood. Nevertheless, there is general agreement in recent models and studies that the monsoon will at the very least become more variable in the coming decades. Various studies, including those from the Intergovernmental Panel on Climate Change (IPCC), indicate that on a general level the summer monsoon (June to August) will become more ‘intense’, but also more variable, meaning more frequent heavy rainfall events,

even as the number of rainy days decreases (IPCC 2007). Although monsoon rainfall projections for Nepal do vary, more models suggest an increase rather than a decrease towards the end of the century: -14 to 40% by the 2030s; -40 to +143% by the 2060s; and -52 to +135% by the 2090s (NCVST 2009).

Further studies indicate that multiple variables, including major land use changes, increasing aerosol emissions, and elevated CO_2 levels due to CC, could all potentially trigger abrupt transitions between two stable states of the monsoon in a "roller coaster scenario," leading to either a more dry monsoon, with significantly less precipitation than current levels, or a more wet monsoon, with much greater rainfall intensity (Zickfield et al. 2005). These authors conclude that the monsoon would most likely be weakened initially, leading to a dryer state in the short term due to the effects of land use changes and greater aerosol production from increasing industrialization on the Indian subcontinent, followed by a more wet monsoon in the long term as the effects of increased CO_2 levels become increasingly significant.

Further conflating any understanding of predicted changes to precipitation levels are these effects of aerosols like black carbon or soot. Such effects are primarily felt through atmospheric brown clouds (ABCs), "regional scale plumes of air pollution that consist of copious amounts of tiny particles of soot, sulphates, nitrates, fly ash and many other pollutants" that hover over parts of the globe (including South and East Asia) with concentrated industrial emissions, limiting summer monsoon rainfall, contributing to glacial retreat in mountainous regions, and ultimately affecting crop yields (Ramanathan et al. 2008). According to United Nations Environment Programme (UNEP), "ABC-induced dimming" of surface solar radiation is the primary cause for reduced rainfall in India over the last 20 years (Ramanathan et al. 2008). Previous studies had indicated that the effects of ABCs actually offset some of the negative impacts of increased CO_2 levels, but more recent work indicates that the overall combined effect of ABCs and increases in greenhouse gas emissions negatively impact crop yields (Auffhammer et al. 2006).

Runoff

The effects of the changes in precipitation and temperature are expected to change the balance between 'green water' and 'blue water'. 'Green' water is the water that is used or lost in catchments before it reaches the rivers, while 'blue' water is the runoff that reaches the rivers. Glacial melting and retreat, rapidly thawing permafrost and continually melting frozen soils in higher elevations is already being observed (Eriksson et al. 2009). In the subbasins dominated by glaciers, this will mean increased downstream flows in the short term, but in the long term, runoff is expected to decrease with the retreating glaciers, causing major reductions in flow and significantly affecting downstream livelihoods and ecosystems (Bates et al. 2008). In the winter months, more precipitation is falling as rain, which also accelerates deglaciation, and in turn means a shorter winter and earlier snowmelt, ultimately affecting river basins and agricultural systems dependant on surface water diversions for the summer growing season.

Another particularly significant threat in the Himalayas and directly correlated to rising temperatures are glacial lake outburst floods (GLOFs) that result from rapidly accumulating water into glacial lakes that then burst, sending flash floods of debris and water from high elevations, wreaking havoc on downstream communities and damaging valuable infrastructure like hydropower facilities and roads. There are approximately 9,000 such lakes in the Himalayas, of which 200 are said to be in danger of bursting (Bajracharya et al. 2007). High rates of glacial melt due to increases in temperature are adding to this threat, as the rate of such incidents increased between the 1950s and 1990s from 0.38 to 0.54 events per year (Bates et al. 2008).

TABLE 1. Anticipated climate change impacts in Nepal.

Temperature	•	Significant rise in temperature:
		➢ 0.5 to 2.0 ºC by 2030
		➢ 1.3 to 3.8 ºC by 2060
		➢ 1.8 to 5.8 ºC by 2090
	•	Increase in the number of days and nights considered hot by current climate standards
	•	Highest temperature increases during the months of June to August and at higher elevations
Precipitation	•	Wide range of mean annual precipitation changes:
		➢ -34 to +22% by the 2030s
		➢ -36 to +67% by the 2060s
		➢ -43 to 80% by the 2090s
	•	Increase in monsoon rainfall towards the end of the century:
		➢ -14 to 40% by the 2030s
		➢ -40 to +143% by the 2060s
		➢ -52 to +135% by the 2090s
Runoff	•	Higher downstream flows in the short term, but lower downstream flows in the long term due to retreating glaciers and snowmelt and ice-melt
	•	Shift from snow to rain in winter months
	•	Increased extreme events, including floods, droughts and GLOFs

Source: Figures for anticipated changes in temperature and precipitation (NCVST 2009; McSweeney et al. 2008); figures for runoff (Bates et al. 2008; Eriksson et al. 2009).

Climate Change Impacts on Agricultural Systems

The effects of CC on agriculture in Nepal can be divided between systems that are dependent on the summer monsoon and those that are dependent on snow, ice and glacial melt. Agricultural systems dependent on water sourced from snow, ice and glacial melt will see an immediate increase in water supply, but will also be in greater danger of GLOFs that threaten crops, water infrastructure, and mountain livelihoods, in general. Whether such an increase will consequently increase productivity in the short term is unknown, as very little exists in terms of water storage in Nepal, however primitive, to harvest such an excess of water supply. Long term, the effects of reduced water storage and variability of supply from earlier thawing of the snowpack and deglaciation have the potential to be significant, with glacial melt accounting for 30% of per capita consumption in some lowland regions (Eriksson et al. 2009) and increases in temperature causing consequent increases in agricultural water demand (IPCC 2007). Unfortunately, because these effects are not likely to be felt for decades, the short-term benefits of increased runoff will likely delay any comprehensive long-term proactive management plans.

For systems dependent on the summer monsoon, multiple scenarios are possible due to the pervasive uncertainty in the models and lack of data, including the ‘roller coaster’ discussed previously, where the monsoon could abruptly transition between ‘dry’ and ‘wet’ states. In the short term, however, when taking into account the effects of increased aerosol production and ABCs, there is more certainty that less precipitation is likely to occur during the summer months as the number of rainy days decreases, even though the frequency of intense rainfall events will increase (UNEP 2008). Increasing variability of precipitation patterns will have a significant effect on crop productivity, as farmers will have to adapt to changing onset and termination dates of the monsoon. Later start dates significantly impacted rice crops in 2009, as many seedlings were lost

due to the delay in rainfall, and many did not have enough time to mature enough for a viable yield (Subel 2009).

The impacts of less water during the dry months are much easier to visualize, as recent winter droughts have continued to show the effects of low water supply. During the drought of fall 2008 to spring 2009, agricultural systems experienced significantly reduced crop yields, resulting in food insecurity for millions. Such effects would be augmented by a more intense dry season. Western regions will be the most detrimentally affected because they rely heavily on winter rains and cannot depend as reliably on summer monsoon rains, which are not as intense in the west due to the natural pattern of rainfall intensity from east to west (HMG 2005).

Though determining how agricultural systems in Nepal will be affected by the potential impacts of CC is difficult due to the lack of data in the country and the uncertainty in the climate models, there is nevertheless little doubt that significantly more pressure will be placed on food systems that are already incapable of feeding the domestic population. Extreme poverty and high levels of malnourishment make even the slightest fluctuation in climate potentially disastrous to the economy. The population is thus extremely vulnerable, not only to longer term CC that will ultimately reduce water availability and limit crop productivity, but even more so to the immediate threats of increasingly frequent GLOFs, landslides, flash floods and droughts.

In order to avoid the worst-case scenario, it is, therefore, crucial for Nepal's national leaders and resource managers to draft and begin implementing effective and comprehensive national adaptation plans for both the short and long term. In order for such planning to be effective, however, it is critical to gain a more comprehensive understanding of the institutions potentially involved in the adaptation process, both in terms of the constraints they face and their current capacity. Section III, *Mapping of Relevant Institutions for Climate Change Adaptation*, first defines adaptation, then provides such an analysis, mapping adaptation for relevant institutions from both the national and local levels.

MAPPING OF RELEVANT INSTITUTIONS FOR CLIMATE CHANGE ADAPTATION

Strategic and Autonomous Adaptation

There are two main branches of adaptation commonly cited in the literature: autonomous and strategic (Bates et al. 2008; NCVST 2009; Smit et al. 2000). Autonomous adaptation refers to the actions of individuals taken at the household level to make changes that reduce vulnerability to a changing climate, regardless of planning, policies and strategies implemented at the national level. For instance, agricultural households can apply different management techniques that involve less water use, greater cropping intensity, crop diversification, micro-irrigation and small-scale storage, or anything that improves the resilience of the income base during fluctuating conditions. In the near-term, autonomous adaptations in agro-economies, such as Nepal, will focus on shifts in agricultural and water management; however, income diversification is likely to become the primary autonomous adaptation strategy in the long term. Major changes like migration to urban centers, off-farm employment, remittances from abroad, or new businesses that capitalize on greater access to markets provided by advances in information technology and other infrastructure are already used as a means of adapting to changing circumstances.

The word autonomous is to some extent misleading, as many of the autonomous adaptation options available directly depend on "systemic factors that enable people and organizations to

take advantage of opportunities" (ISET 2008, 6). It is these baseline systems, whether ecological (agriculture), information technology or transportation infrastructure, on which the versatility of local livelihoods directly depend, and how autonomous adaptation is directly connected to strategic planning. In many cases, without some national level strategic planning, those autonomous adaptation options mentioned above are not possible. For instance, in many cases, income diversification is inherently dependent on infrastructure that can only be provided from the top down. Thus, although autonomous adaptation involves automatic actions taken at the household level in response to changing conditions, the variety of options for those actions is in many cases entirely dependent on national level strategic planning.

Strategic adaptation refers to planning, policies or strategies at the national level that proactively responds to the potential effects of CC. This includes direct construction of infrastructure, capacity building, disaster relief planning or a host of different methods that increase national resilience to the potential impacts of CC on both ecosystems and human populations. Because most of these impacts will be felt primarily in water resources, in both developed and developing countries, strategic adaptation planning is fundamentally about water management (Bates et al. 2008). For a country like Nepal that is so heavily dependent on agriculture for livelihoods and GDP, the impacts of CC on water resources are of critical importance. Strategic planning will thus entail emphasizing newer more sustainable agricultural techniques that are less water intensive, refocused efforts on the rehabilitation of water infrastructure and development via expansions in storage and irrigation, and reevaluating water management within the context of the impacts of CC.

Though the majority of CC impacts will be felt in water resources, understanding how they are connected to basic development and poverty alleviation at the household level is also a crucial part of any strategic adaptation planning. In a broad lesson from water resources development in the past, such planning should not be limited solely to water resource issues, but should also focus on "enabling autonomous adaptation processes by supporting the development of flexible, resilient, and accessible social and physical infrastructure systems…" (ISET 2008, 6). This means that many of the current projects and avenues for expanding development and improving the livelihoods of the millions of poor in South Asia through the creation of greater access to markets via infrastructure like roads, electricity and telecommunications would also be included in the strategic adaptation process.

In order to provide greater clarity of this adaptation framework in Nepal through concrete examples, the following section will focus on the institutions that are relevant for this process from the national to local levels. Using a case study analysis of the Salleri development region within the Dudh Koshi Basin, a subbasin of the Koshi River Basin, and an analysis of the central level planning framework, a distinct picture emerges of the institutional structure of policy implementation in the country.

Institutional Mapping for Climate Change Adaptation in Nepal

Assessing the various institutions in Nepal and their specific functions can be an exceedingly difficult task when including all of the different development and aid agencies, United Nations (UN) programs, international development banks and hundreds of NGOs. Focusing solely on the government side, the picture becomes somewhat clearer, but due to the constantly changing political situation of a four year old democracy and a history of changing institutional structures, a confusing map of ministries and departments exists, where determining the exact responsibilities of specific institutions is challenging, especially when considering only a theoretical role in the adaptation process.

This section will provide a general analysis of the institutional structure at the national level, setting the stage for a case study that evaluates the institutional arrangements at the local level. It will then provide a theoretical analysis of the roles of institutions in CC adaptation.

Institutional Structure at the National Level

At the national level, water policy is primarily orchestrated through the Water and Energy Commission Secretariat (WECS), which acts as a central clearinghouse for water and energy policy and also wrote Nepal's most current National Water Plan (NWP) published in 2005. As advised in the NWP, WECS was to be given much greater authority in the oversight of policy formulation, coordination of implementation, interagency planning related to water resources, as well as budgetary oversight; however, this has yet to occur and its mandate remains weak. With no budgetary power, WECS has to go through other ministries to approve projects. Moreover, the state of implementation of the NWP remains minimal, and it has received less priority as a result of major changes in the government structure, continuing political uncertainty and a lack of capacity. Also, many of the district and local level institutional arrangements and reforms advocated in the plan have yet to be addressed.

WECS was created to function as the water policy arm of the bureaucracy, creating policy to be implemented by the various line ministries, such as irrigation, energy, environment, agriculture, and livestock, with each of the relevant Secretaries sitting on the Water and Energy Commission (WEC) chaired by Minister of Energy. Figure 1 elucidates the role of WECS among the various relevant national institutions.

It is apparent from Figure 1 that, at least in theory, WECS is central to the water policy structure at the national level, though as noted in interviews with officials and in existing literature, it still lacks a firm mandate (Kayastha and Pant 2001; Dhungel pers. comm.). If the political situation stabilizes and WECS is able to secure its mandate through the passage of institutional reform laws, it will enjoy much greater power in reforming water mangement.

Institutional Mapping at the Local level – Koshi Basin

The analysis of the local level (i.e., district and community level) is based on research conducted in the Solukhumbu Development District in Nepal's Dudh Koshi Basin, a subbasin of the Koshi Basin. Figure 2 shows the Koshi River Basin and the Dudh Koshi River. The Koshi Basin is the largest in Nepal, covering 17 development districts of two of the country's development regions, 10 subbasins and nearly 30,000 km^2 of land in Nepal from the Himalayas to the agricultural lowlands of the Terai (WECS 1999). It is an ecologically and topographically diverse basin, with significant biodiversity, a Ramsar site, and two national parks, Langtang and Sagarmatha, the home to Mount Everest, which contributes in providing tourism jobs and dollars to the region. The Koshi is one of the three largest rivers flowing from the Nepalese Himalayas into the Ganges, contributing the majority of its flow during the dry season and almost half during the summer monsoon. There is massive potential for water resources in the basin that remain largely untapped, with government estimates indicating that only 14% of the total available 4.8 BCM of water is being utilized with a potential capacity to generate almost 30,000 MW of hydropower and irrigate nearly 500,000 ha of land (WECS 1999).

Such potential is not lost on the national government, which has been attempting to build a high dam on the Koshi for decades, but due to diplomatic difficulties with its Indian neighbors, it

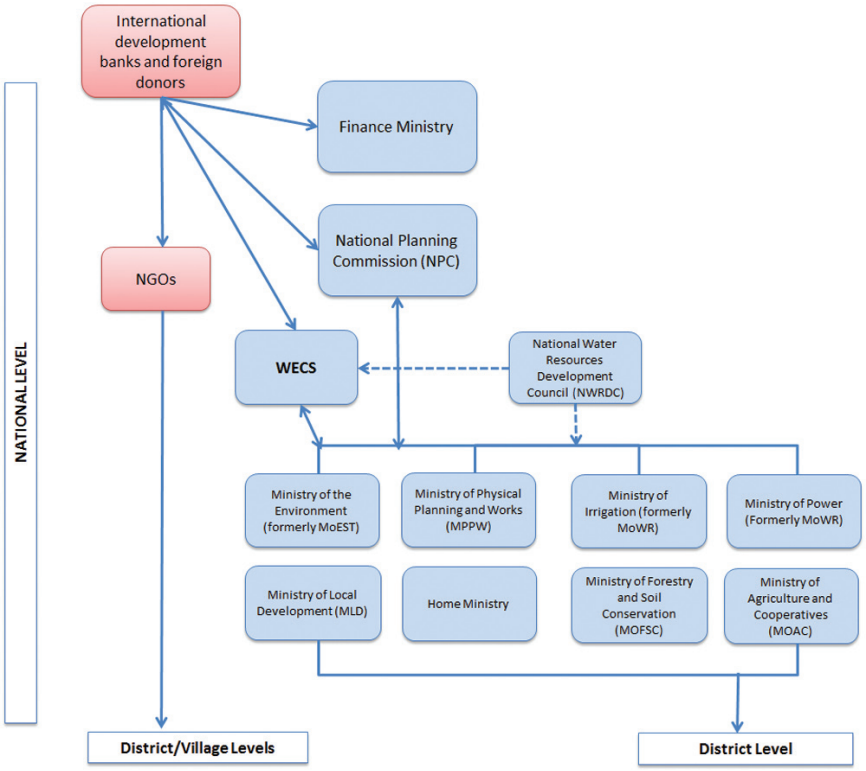

FIGURE 1. Mapping of relevant national development and water resources institutions. *Note*: Government institutions are in blue and private institutions are in red. The process of policy and project implementation flows from top to bottom, where the budget from the finance ministry, the majority of which coming from bilateral and multilateral donors as loans and grants and covering nearly 70% of the annual budget of the government, dictates what the National Planning Commission (NPC) can plan for.The program is decided between the line ministries and the NPC, and then implemented at the district level. The National Water Resources Development Council (NWRDC), chaired by the prime minister with representation from related ministries and experts from outside, sets policy guidelines both for the line ministries and WECS on water resource issues. WECS, at the center, liaises with all relevant institutions, including the donors. Two-way arrows indicate communication/cooperation on budgets, projects and policy frameworks.

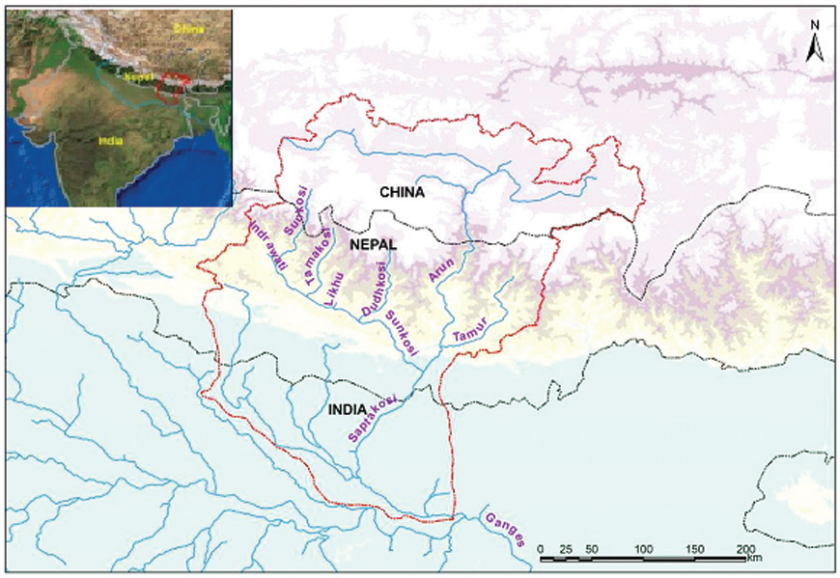

FIGURE 2. Map of the Koshi Basin with main tributaries. *Source*: International Centre for Integrated Mountain Development (ICIMOD).

has been unable to agree to any bilateral conditions. India has a very direct interest in the Koshi for a variety of reasons, including its potential hydropower generation and irrigation supply for Indian use, but it is also relevant for the annual flooding in the Indian State of Bihar, where the Koshi is known as the "Sorrow of Bihar" for the impacts of floods on local populations. On August 18, 2008, the Koshi River picked up an old channel it had abandoned over 100 years ago near the border with Nepal and India. Approximately 2.7 million people were reported as being affected as the river broke its embankment, thus submerging several districts of Nepal and India (NCVST 2009). Ninety-five percent of the total flow of the Koshi was reported as flowing through the new course. The Koshi is thus a significant river basin for a variety of different environmental, economic and political reasons and for maintaining foreign relations, with many different institutions, from international non-governmental organizations (INGOs) and development banks to government ministries focused on the basin. At present, the only large infrastructure project is the Koshi barrage near the Indo-Nepal border, also called Bhimnagar Barrage after the name of the place where it was built between the years 1959 and 1963. It is an irrigation, flood control and hydropower generation project built under a bilateral agreement between Nepal and India. The entire cost of the project was borne by India.

Dudh Koshi Subbasin: Solukhumbu Development District

The Salleri development region of the Dudh Koshi Subbasin is a remote region with elevation changes from 300 to 3,000 m where roads do not connect outside the district and commuting from village to village is often a 2 to 5 hour trek on foot over rough trails and with significant changes in elevation. There is some airport access, but only for limited weekly flights that primarily serve bureaucrats and some chartering for goods. Income sources are diverse for local populations close to the airport, with small businesses in everything from handicrafts, hotels, and restaurants, to contractors and water bottling, and jobs at district government offices of the line ministries in agriculture, forests, education, etc., also providing alternative sources of income. The tourism sector also provides a source of income for the community. Generally, however, underemployment, as is the case throughout Nepal, is high. As one travels farther away from the airport, levels of development quickly and noticeably decline, and the primary source of income becomes agriculture, as transportation is limited to foot and by donkey, with raw materials exceedingly expensive and local communities essentially closed off to outside markets due to high transportation costs and lacking roads.

Agriculturally, the sub-climate of the hills in and around a few villages visited on foot is suitable for different types of crop production and infrastructure development. Farmers living at higher elevations and on the "up side" of the catchment primarily rely on rain-fed systems for growing maize, millet and potatoes with some fruit trees being introduced, and almost all have some form of livestock. Some farms are fed by irrigation via multiple-use micro-hydro that also provides drinking water and electricity, but such systems are limited due to the high costs of construction and general feasibility problems associated with such isolation and topography. Turbines, for example, have to be flown in by helicopter, which is an astronomical cost for the few hundred small villagers (who earn less than US$1/day) that would be directly benefitted. The upper side of the catchment, depending on exact geographical location, is usually water scarce in the winter months, and sometimes faces significant reductions in supply due to the variability of the summer monsoon, which as discussed previously, is only likely to increase in the coming decades with the impacts of CC.

In the lower side of the catchment, irrigation is more prevalent than in higher elevations due to the needs of flooding rice terraces and the generally more geologically feasible topography, but it is also limited in scope. All of the irrigation projects are diversions from streams or springs. There is

no storage infrastructure for the monsoon runoff, so if streams or springs dry up during the winter months then water supply is cut off. Rice is grown due to changes in climate and normally where there is greater water supply alongside maize and millet with some limited fruit trees, vegetables and livestock production. Families are also generally more dependent on the land in these areas for livelihoods, with fewer income diversification options than those at higher elevations. Part of this can be attributed to caste differences, with *Sherpas* at higher elevations being more connected to the tourist industry in the district. In terms of infrastructure, electricity is present but severely limited in scope to where micro-hydro systems have been installed.

Whether the direct result of anthropogenic CC or a consequence of natural variability, the effects of a much weaker monsoon were evident, particularly in relation to crop production in 2009. As a result of a 30% weaker monsoon, many rice terraces were left unplanted due to a lack of sufficient water, and many rice crops that were planted dried out and left unusable due to the delay in consistent rainfall. Rice, a water-intensive crop, is the most affected due to the lack of rainfall and irrigation in many hill communities, which ultimately means that it has to be imported during some years, raising its cost beyond what many families can afford and thus creating pervasive problems of food security. Such was the case during the summer and fall of 2009 when paddy and maize harvests were reduced by 11 and 4%, respectively, due to a much later onset of the summer monsoon (GoN 2010).

Erosion and landslides are the most pressing and dangerous natural disasters in the region, occurring annually with significant frequency during the monsoon season. Though the exact connections between CC, the monsoon, and its resulting effect on the occurrence of landslides are unknown, predicted increases in intense rainfall events are likely to consequently increase their prevalence.

The following section will describe the general institutional framework of the Salleri development region, based on observations in the villages of Phaplu, Salleri, and Nelle Bazaar. Because basic knowledge and capacity regarding CC are so deficient nationally and even more so in these communities, not only are the impacts of CC not well understood, adaptation is essentially nonexistent in theory or practice. Any assessment of institutions involved in adaptation at the local level in Nepal is therefore a theoretical exercise, but those already involved in poverty alleviation, bringing greater access to markets, basic development, and especially those governing water resource management, are in many ways already addressing adaptation by increasing resiliency of local populations to the future impacts of CC through greater income diversification. For many citizens and Nepali institutions, adaptation will thus not require fundamental new programs and projects, but rather the integration of adaptation into current development planning, where interventions that build resilience through income diversification while planning for the ultimate future impacts of CC must be prioritized.

District and Community Level Institutional Framework

The line ministries and their departments at the local levels are important in water resources development and management, in particular, the ministries of Physical Planning and Works, which look after rural water supply and sanitation; and irrigation, energy, and agriculture. Because of recent structural divisions that reflect a history of constantly changing institutions and their mandates, their exact roles and departments are, however, in a current state of flux. Also important, but more generally involved in development policy, are the ministries of Home Affairs and Local Development. The Ministry of Home Affairs, responsible for the general administration at the district level, appoints the Chief District Officer (CDO), who is also the Chair of the District Water Resources Committee

(DWRC) who handle some general water resource issues, water licensing and resolve disputes but is mainly responsible for registering Water Users Groups for irrigation, permitting micro-hydro power construction, and rarely carries out these other functions (Kayastha and Pant 2001).

Institutional structure at the district level is also somewhat complex, but generally follows the framework for the Solukhumbu District as outlined in Figure 3. This current structure is considerably less democratic than it was in the late 1990s and early 2000s, when the District Development Committees (DDCs) and Village Development Committees (VDCs) were elected bodies of local citizens, and thus much more accountable. Even four years after the end of the second revolution in 2006, elections have yet to be held, and instead these bodies are run by appointees of the Ministry of Local Development (MLD) often from outside the community. Regardless of the lack of elected representation, these are still the most powerful institutions at the district and village levels.

Functionally, both the VDC and the DDC have their own allocated funds from the central government at the beginning of the fiscal year in July, and also from the local revenue collection which they are entitled to collect according to the Local Self-Governance Act of 1992. When the VDCs and DDCs are functioning properly, they comprise elected individuals that make district development plans with help from line agencies at the district level that are then submitted to the NPC for approval. However, in their current state, all functioning is handled by the Local Development Officer (LDO), thus reducing their capacity significantly, which has a consequent effect of reducing the general level of development. Once the plans are submitted to the NPC, it

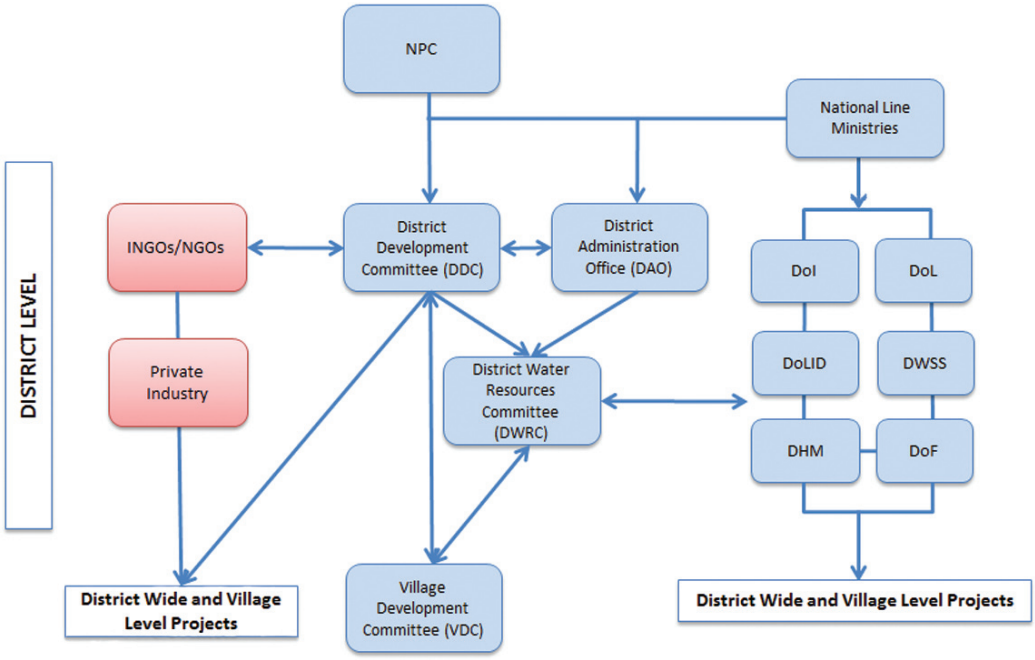

FIGURE 3. Institutional structure of Solukhumbu District. *Notes*: Project and policy implementation flow from top to bottom, from the NPC to the VDCs at the community level. Line ministry departments, like Irrigation (DoI), Livestock (DoL), Water Sanitation and Supply (DWSS), Forestry (DoF), Local Infrastructure Development (DoLID), and Hydrology and Meteorology (DHM) have their own budgets for implementation within the district. The DDCs work separately from the ministry and departments, with some funding for the VDCs, but implement their own development projects at the district level as well. The DWRC is mandated to liase between the ministry, departments and the DDC. Currently, there are no elected representatives at the local level institutions – DDC/VDC, leading to a structure that is more top down in nature, and dominated by the government in Kathmandu. Though there is some organization with government institutions, INGOs and private industry work primarily outside the government.

can often take as long as six months for approval to take place and for government funds to be allocated to these committees at the local level, which is particularly constraining for the DDC because it has to spend allocated funds within that fiscal year otherwise the funds are returned to Kathmandu. Thus, in some cases, there is only five or six months to implement entire projects, leading to hurried and substandard work, and a perverse incentive to spend resources aimlessly.

Plans of the VDC also have to be approved by the NPC, but spending of funds is not limited to before the beginning of the next fiscal year. The budget is, however, constrained to the original requests, and if, for example, nothing was requested for disaster relief (which does not usually occur unless there is a disaster at the time of the request) there are no relief funds for when disasters do actually take place.

The VDC secretary, also a nationally appointed LDO in charge of the local VDC, faces different hurdles in implementing local development policies. Many VDC secretaries have, for example, continued to work out of the district headquarters since the beginning of the insurgency due to safety concerns and have yet to return even four years after the signing of the peace agreement. There are also a number of other factors beyond safety that provide an impetus for them to stay primarily in the district headquarters, either due to control over multiple VDCs or a general desire not to be so isolated in the villages, that continue to hamper government effectiveness and capacity at the local level. One such individual in the Salleri region is responsible for 10 VDCs (as is the case for many of the remote development districts in Nepal), which has an obvious effect in reducing the responsiveness of the VDC when it takes longer than 5 hours to walk to some of the villages from the district headquarters in Salleri.

There are also hundreds of NGOs active at the local level in Nepal working directly with local populations on a spate of issues and projects, but often with little coordination with government programs. The reasons for this are numerous, but most directly due to the lack of transparency, oversight and effectiveness in government institutions that have provided enough incentive for INGOs to avoid the government. Unfortunately, this has sometimes led to a mutual feeling of mistrust between the two sides, and a sense of resentment from government officials that the NGOs are turning local populations against them by creating impossible expectations of the local government. Based on observations in the Salleri region and conversations held with locals, NGOs seem to have been more effective in implementing projects and improving the livelihoods of local populations, especially in remote areas, than local level government institutions.

Theoretical Institutional Adaptation Framework

Given the infancy of CC and adaptation issues in the national discourse, determining those institutions involved in the adaptation process is a somewhat difficult task as many national and local organizations are only now beginning to plan for the impacts of CC. It is nevertheless valuable to map those that will be the most salient in the coming decades to determine their relative capacity in dealing with the effects of CC. Returning to the adaptation framework presented previously in this paper, there are institutions that will be more central to strategic adaptation and others that are more relevant for autonomous adaptation, but with considerable overlap across the two types.

The National Level

Relevant government ministries are a critical element of the adaptation process. The Ministry of Environment has been designated the focal ministry for CC activities by the government, which

in November 2009 formed a high level body chaired by the prime minister to provide policy directions for CC activities. The ministries, including public works, irrigation, energy, agriculture, environment, and hydrology and meteorology, among others, will all be crucial in continuing to expand development that is both necessary in providing the basic development skeleton for Nepal, but also in developing projects that are specific responses for CC adaptation, whether it be new, more sustainable agriculture approaches, greater storage capacity for water supplies, early warning systems for GLOFs, etc.

WECS will also be crucial for strategic adaptation planning if ever given the proper mandate written in the NWP. As a central, sole institution for water policy that can then filter information down through the ministries and their departments at the local level, it can be used, especially if the democratic framework of locally represented water management organizations called for in the NWP comes to fruition, to disseminate information on the impacts of CC and how to adapt effectively to them. As the primary water management body, WECS is thus crucial in reorienting national management and development plans around CC, and in building capacity and filtering information down to the local level.

Ideally, WECS would serve as a central disseminator of strategic CC adaptation policy to all the ministries, who would then incorporate such policies into their development plans for the NPC and filter them down to the district and village level department offices. However, due to the current state of political instability and stagnant government actions, the prospect of WECS having such capacity in the near future is slim. In the meantime, a focus on implementing existing plans would still help families at the household level adapt to CC by providing more consistent energy supplies from hydropower expansion and irrigation (the "systemic factors") that allow, at the very least, some greater opportunities for income diversification. This is not advocacy of the status quo; there are numerous political and institutional hurdles (described repeatedly in this paper) that need to be overcome even before this can occur.

The support from relevant international actors at the national level, including INGOs and donors, will also be critical in the adaptation process. INGOs will be necessary to continue to implement plans and projects in markets and locales where the government has not been able to reach for a variety of reasons, as well as in offering the training and technical capacity development that is so necessary throughout the bureaucracy. The donors will play a crucial role, as they have in the past, in guiding the basic national development policy, and are the most capable of integrating adaptation into long term development plans. They are inevitably the most powerful when it comes to development progress due to their contributions comprising the majority of the national budget, and there are signs that they understand the significance of addressing adaptation planning, with multiple projects by the Asian Development Bank (ADB), World Bank and UK Department for International Development (DFID).

In terms of autonomous adaptation, because NGOs and donors are so involved in all the planning and development in Nepal, they will also be instrumental in providing opportunities for income diversification through various poverty alleviation programs, but even more so through support of the "systemic factors" that are inherent in creating more options for households in livelihood generation. Crucial in their role as large capital investors, the donors will continue to be an inherent part of increasing options for livelihood sources, and thus encourage the autonomous adaptation process via large capital infrastructure projects like roads, water storage and power facilities, irrigation and transmission lines that are important for the country's basic development progress. Private capital investors from neighboring countries and elsewhere are increasingly important for the overall development of water resources.

District and Village Levels

Though not currently functioning in their original constitutionally mandated structure, the DDCs and VDCs at the local level will still be the most crucial institutions for both strategic and autonomous adaptation. Strategically, because the impacts of CC will affect so many different aspects of life at the local level due to such a high number of climate-dependent livelihoods, as the central development and organizing bodies, these institutions will play a critical role in the implementation of any adaptation planning that comes from WECS and the ministries at the national level. These institutions could also play a role in encouraging increased autonomous adaptation. In their current state, however, they already struggle to implement basic development plans for a host of reasons, including the duties of a committee being limited more or less to one person, the lack of oversight, constant corruption problems, ineffective governance and general political instability. Creating new sources for income diversification and increasing the prospects for autonomous adaptation is, therefore, already a struggle, making any attempt at strategic adaptation, without mitigating some of these problems, somewhat futile. Nevertheless, these institutions, as the most important government bodies at the local level, will be the most relevant in implementing not only basic development planning, but also any attempt at future strategic adaptation.

There are a number of theoretical local level institutions called for in the NWP that would also be an inherent part of the adaptation process if the plan were ever made operational. Based on an implementation framework in the NWP that calls for a spate of decentralized water management committees (at the local levels) that serve to some extent as local WECS cells, including DWRCs and river basin organizations (RBOs), they would be useful for operationalizing any adaptation planning coming from WECS at the national level, but due to the number of political constraints over the last 5-10 years they are only now beginning to get off the ground with just a few pilot examples being created. Such committees, if ever successfully created, would be ideal institutions for spreading knowledge and building capacity on CC impacts and strategic adaptation options at the local level because they would work directly with water resource issues, coordinate with national WECS policies, and inherently involve the participation of local citizens.

The line ministries, as the other arm of the government, will also be critical for strategic adaptation planning at the local level. If WECS is given the proper mandate for formulation of water policy at the national level, then these ministries, like irrigation, agriculture, physical planning, and construction would theoretically implement those policies, but through their own specific sectoral goals and frameworks, and thus be inherent in implementing strategic adaptation planning. Unfortunately, like the DDCs and VDCs, departments within these ministries also face multiple constraints in doing so, including the overarching national problems of ineffective governance, political instability, and a lack of capacity and resources.

Also important in both strategic and autonomous adaptation are the hundreds of groups at the village and district levels that both provide support to the population through health, legal and other services and work directly with INGOs and the government in planning and project implementation, including various user groups and committees, whether for micro-hydro, irrigation, drinking water supply, electricity or other infrastructure. Such groups provide yet another opportunity for dissemination of information on the potential impacts of CC to the household level, strategies for adapting to them, as well as general support for income diversification. These institutions are also some of the most important, alongside private industry and INGOs, in directly supporting autonomous adaptation. Like government institutions, these groups are also lacking capacity at the local levels and would need to be educated on the impacts of CC and strategies for adaptation before they could be useful in any strategic adaptation planning. However, at the moment, they

will be crucial in supporting the kinds of income diversification opportunities at the local level where the government cannot.

Though this is a discussion of the theoretical roles of institutions involved in adaptation, there are at least some current projects that explicitly address more concrete adaptation methods and strategies in local communities.[1] International and domestic NGOs are the primary actors in the Solukhumbu District (and in other districts) with programs that directly educate local communities on new farming and water management techniques that will be crucial as CC impacts like variations in water supply become increasingly adverse. Unfortunately, such projects are limited in scope to a few villages due to limited budgets, and due to a general lack of coordination between NGOs and the government, their effectiveness is limited. NGOs are still crucial in this kind of capacity building, training and disseminating information, but because the impacts of CC will have such widely reaching effects, teaching new water management strategies to a few isolated mountain and hill communities without more coordination with the government is simply insufficient. A much more comprehensive effort, orchestrated by a coordinated group of INGOs/NGOs/donors/national government will be necessary to implement any effective adaptation that ensures the long-term resiliency of local populations.

CONSTRAINTS TO ADAPTATION

In comparison with many developing nations that have also signed the Kyoto Accords, Nepal was far behind in developing a national adaptation plan, including its National Adaptation Plan of Action (NAPA) for the United Nations Framework Convention on Climate Change (UNFCCC) and the document has just recently been approved by the government. A direct result of institutional and governance problems, the national discussion on adaptation - let alone CC – has only begun relatively recently. There is a dearth of capacity at all levels of the bureaucracy, from extremely isolated local communities to leaders in Kathmandu, with little understanding as to how potentially detrimental the impacts of CC could be for a Nepali economy that is so reliant on agriculture which accounts for 35% of GDP and 76% of the labor force (CIA 2010). Conversations with some resource managers show a perspective of responsibility on the developed world to "fix the problem," and some apathy as to what a small nation with so many existing constraints that prevent even basic development can do about it. That the current political situation is so mired in embittered party politics and with the pace of writing the new constitution for the fledgling democracy at an ebb, indications are that the adaptation process will continue to languish. Some of the major constraints to adaptation are outlined below.

Dependence on Subsistence Agriculture

Though there are some indications that incomes are diversifying as people migrate and take advantage of new options that were not available to previous generations of farmers, there are wide swaths of the country where dependence on subsistence agriculture still dominates and options for improving resilience in the face of imminent impacts from a changing climate are slim. Major percentages of the population are entirely vulnerable to even the slightest fluctuation in climate.

[1]See http://nepal.panda.org/our_solutions/projects/index.cfm?uProjectID=NP0909 for information on a World Wildlife Fund (WWF) project teaching adaptation techniques to one community near Langtang National Park, Nepal.

This is especially the case for remote areas outside Kathmandu that lack basic transportation infrastructure (roads) that are, as a consequence, vastly underfunded by the government and INGOs due to the incredibly slow pace and high costs of any project. Raw materials, technical consulting expertise and other costs become so exorbitantly high due to the lack of open access to outside markets and transportation options that the government and INGOs are unwilling to invest in, resulting in a vicious cycle of stagnating development, where costs are high, in part, because of the lack of development.

The figures for agricultural growth and development reflect these patterns. The average growth rate of agricultural GDP during the period 2000/2001 to 2005/2006 was 2.8%. This is indeed low and only slightly above the population growth rate. What is also equally striking is the very high degree of fluctuation from year to year. The growth rate was 5.5% in 2001/2002 and only 2.2% in the following year. Likewise, it was 3.9% in 2003/2004, only to slide back in the following year (MOF 2007). The performance in 2005/2006 was the worst in recent years, attributable to adverse weather conditions that affected rice, wheat and barley crops.

Challenging Geophysical Conditions

The extreme and beautiful geography of Nepal, though a boon to the tourist industry and the source for such ample natural resources, is also an inherent reason why development levels are so low. Topography is a particularly worrisome concern for the potential adaptation process because it will be one of the most difficult to overcome, requiring massive and consistent investments in concentrated road development, which is an arduous process even for developed nations. Investing more in water resources infrastructure, a crucial aspect of adaptation for the developing world, is also severely limited by the extreme topography of the middle hills and upper mountains of the Himalayas that make for inherently unfeasible large storage and irrigation facilities that would otherwise help with a changing and increasingly variable water supply. The options available for improvement in these areas are thus extremely limited both because of high costs and geophysical constraints.

The isolation created by extreme changes in geography has both direct effects in limiting access to markets and creating high costs for development, but also other indirect consequences as well. Capacity building and effective governance are limited due to the simple difficulties of trying to extend the arms of the national government's oversight to remote villages that in many parts of the country can only be reached by 5 hours walking from airports with intermittent flights during the monsoon, and the difficulties faced in organizing people and sharing information across such large and extreme changes in elevation. Advances in information technology in recent decades have the potential to mitigate some of these problems, but without basic electricity, cell phone towers and phone lines, such advances mean little.

In terms of natural disasters in Nepal, topography related isolation will also limit the effectiveness of adaptation, both autonomous and strategic, in many areas. Some early warning systems have been created in the upper mountains for threatening GLOFs, but more pervasive and consistent disasters like landslides in the middle hills during the monsoon months that destroy crops and take lives, leave few options for an effective response. Early warning is near impossible due to their frequency of random occurrence, and disaster relief efforts are constrained by minimal resources at local levels and topographical isolation. Furthermore, because levels of income diversification are still so low in the most remote areas and there is a lack of credit and insurance institutions, few options are available to affected families beyond migration, which in itself is not a viable option for even the poorest farmers.

Population Growth in Urban Centers

At the opposite end of such isolation, urban areas are facing constant population growth and migration from rural communities at a rate far beyond what the government is able to keep up with in service provision. Though the most recent trends of urban migration in Nepal are the result of security fears during the insurgency, there is likely to be an increasingly positive correlation between urban migration and the impacts of CC, with more and more "climate refugees" moving to urban areas. An exploding population in Kathmandu (where drinking water supply and access to sanitation are both already limited, and food prices fluctuate wildly) will face new vulnerabilities with the effects of CC. Migration is thus not only an adaptive action for small rural farmers moving to urban areas, but also a constraint to adaptation as exploding urban populations continually struggle to handle such growth. More research needs to be carried out in Nepal as to the exact causes of migration and to what extent CC will lead to future increases in urban population growth as farming becomes increasingly risky and untenable due to the effects of CC.[2]

Institutional Failures and Weaknesses

Alongside the numerous socioeconomic, environmental and geophysical constraints to adaptation facing Nepal, there is a long history of institutional failures that currently complicate the development process and will severely hinder any effective adaptation, either strategic or autonomous. From constantly changing governments, including vacillation between pure royal control to constitutional monarchy and the republic in 2006, and frequent turnover of administrations, Nepal has a long history of political upheaval and impermanent stability. The following are the most relevant failures that will be the most difficult, but essential, to overcome if the most severe effects of the imminent impacts of CC are to be avoided.

Constantly Changing Organizational Structures

The most recent division of the Ministry of Water Resources (what would have been one of the most central actors for any adaptation planning process in Nepal) into two separate ministries, irrigation and energy, is a perfect example of how institutions are constantly changing and restructuring in Nepal. This particular change has resulted in further confusion in water management and dissillusionment among officials at the national level. Likewise, the Ministry of Enviornment, Science and Technology was also recently split into the Ministry of Environment and Ministry of Science and Technology. This is not the first time such restructuring has occurred; the current Ministry of Agriculture and Cooperatives has been majorly restructured nine times since 1967 (FAO-UNDP 2003). Such constant rearranging has an obviously detrimental effect on government effectiveness and continuity of policy, which in turn serves to perpetuate an already stagnating development process.

[2] For a much more detailed analysis of how such urban migration will have an effect on individual livelihoods in a place like Kathmandu, refer to ISET Nepal's *Reimagining the Urban-Rural Framework* (DST 2008), which takes a much more detailed look at how communities on the fringes - where urban meets rural - will be affected by the impacts of climate change.

High Turnover of Government Personnel

Due to the interim nature of the government at present, the transfers of administrators (including all the heads of ministries) that follows a change in the government is frequent. The Ministry of Agriculture, for example, went through eight different ministers and five different secretaries between 1995 and 2000 (FAO-UNDP 2003). In some of the most isolated areas, as observed in Salleri, it is also difficult to find qualified and interested persons for government positions. The Department of Forestry in Solukhumbu, for example, has enough resources to employ 12 forest rangers, but currently only has two rangers due to the lack of interested parties. It is also difficult to find officials that want to work in the most remote regions. Out-migration is also depleting the country of qualified and skilled manpower.

Failures of Public Institutions

Constantly changing structures and personnel have a consequent effect of perpetuating the failures of Nepal's public institutions. There is little oversight, a lack of transparency and extremely low salaries, resulting in little incentive to follow the letter of the law. Many conversations with current and past government officials indicated that bribery is pervasive for reasons no more complex than an inability to pay for a child's secondary education. At the national level, such problems are pervasive, but at the local district and village levels (where there is even less oversight), especially due to the lack of elections for the VDCs and DDCs, the problem can be much worse. Currently run by appointees of the Ministry of Local Development, these bodies are less accountable to local populations that had no say in their appointment. One former elected Chair of the DDC in Salleri indicated that only one-third of project budgets are actually spent on their respective projects.

Ineffective to Nonexistent Coordination

Such problems of high employee turnover and constantly fluctuating institutional structures also serve to perpetuate poor coordination and communication between ministries and departments on a variety of issues. To some extent, for water resources, this has been addressed with the WECS, but because it lacks capacity along with the rest of the ministries in Nepal, very little effective organization and coordination between departments actually ends up occurring. Communication and effective coordination between local and national level institutions is also minimal. In one particularly egregious example, the DDCs have to wait as long as six months for their budgets to be released from the Ministry of Finance, which then only gives them the same amount of time to implement and develop entire projects before the end of the fiscal year, significantly reducing their long-term sustainability due to hurried, shoddy construction.

There is also a severe lack of coordination and communication between NGOs and the government at local levels, with limited official knowledge on the amount of money being spent, the number of projects, and what issues are being focused on. This leads to overlapping projects between the two entities, leading to inefficient resource allocation and confusion for local populations. The reasons for such solitary action by NGOs are apparent and may be justified in some cases, but it also has an unintended consequence of worsening relations with government, which is particularly detrimental for future coordination around adaptation planning. Given the comprehensive nature of the likely impacts of CC facing Nepal, the need for such coordination will be a critical aspect of the adaptation process.

Deficient Capacity

Capacity deficiencies are rampant throughout the Nepali bureaucracy, not only related to the general development process, but even more so in terms of CC and thus adaptation.Though some of the officials of the WECS spoken to indicated a fairly comprehensive understanding of the impacts of CC, it was not apparent that they understood how truly detrimental those effects will potentially be on a Nepali economy so heavily dependent on agriculture, and thus climate. At the local level, some officials were at least aware of CC, but with little idea as to what to do about it or how it might affect livelihoods in their communities.

For many of these local communities, as was the case in Salleri, there are enough current challenges at hand that would prevent any new action being taken on something like CC adaptation. As will be argued in the next section, however, addressing many of these existing development challenges like food security and greater access to water supply and sanitation will be an inherent part of the adaptation process as critical elements of enhancing resilience and reducing vulnerability to CC.

CONCLUSIONS AND RECOMMENDATIONS

With the impacts of CC becoming increasingly more potent, it is clear that effective actions must be taken to improve livelihoods or the country will continue to struggle with political instability as the fight for basic survival teeters on violence. Comprehensive and effective adaptation to CC is a critical aspect of not only maintaining a tenuous peace, but even more important in ensuring food security, poverty reduction and long-term economic development of the Nepali people. With the numerous constraints outlined in this document, especially those related to institutional effectiveness, such adaptation is, however, far easier to write about than implement. With this in mind, the following paragraphs summarize how adaptation must be conceptualized in Nepal, and also how it should be carried out, given the unique context on the ground outlined in this document that makes implementation challenging for a number of reasons.

Returning to the adaptation framework outlined in this document, where strategic efforts will involve the larger, higher capacity national stakeholders, from government ministries to development banks, and where autonomous adaptation will entail the efforts taken at the household level, the picture of implementation becomes more clear. There are, thus, those actions that must take place at the national level (strategic) and at the local level (autonomous). Strategically, the most important conclusion to take away from this document is one that is being made with increasing frequency in the adaptation and development fields. For adaptation to be effective in the developing world, especially in Nepal, it must be a comprehensive effort, involving integrated national planning across all sectors, rather than a separate initiative to be tackled solely by the Ministry of Environment, where projects and programs from multiple sectors are implemented with the impacts of CC in mind.

This is especially important given the state of much of the country's current infrastructure. With a number of massive projects necessary to tackle key issues of food, energy, and water security, it is crucial that CC and its impact on their sustainability and long-term viability is considered. This is especially critical in the agricultural, water resource, and energy sectors facing the majority of the most detrimental impacts that will then ripple outward through the rest of the economy. Irrigation and hydropower projects must be chosen, for example, that solve short-term problems and also account for longer term CC impacts like deglaciation and changes to precipitation patterns of the monsoon.

For autonomous adaptation, the focus must be on building and expanding basic infrastructure at the local level, which will provide the vehicle for increased resilience to future climate shocks through greater income diversification and easier access to markets. Such infrastructure will allow for greater interconnectedness between isolated communities, the national government and NGOs that will continue to provide critical capacity building, all helping to build those "systemic factors that enable people and organizations to take advantage of opportunities." Given that this is such a fundamental goal of basic development, entire planning paradigm shifts to adaptation like that of the national strategic planning process need not occur. For many local communities, adaptation and development will thus be synonymous because as incomes become more diverse and livelihoods improve, so will resiliency toward climate shocks. Isolated rural communities will continue to find it challenging to adapt to the impacts of CC without infrastructure like roads, electricity, water supply and sanitation and, thus, should be considered for any international funding that is specific to adaptation. In the development of its adaptation strategies, for example, Nepal's leaders should heavily consider the development of such basic infrastructure in the project prioritization process.

Ultimately, for either strategic or autonomous adaptation to be successful, the critical institutional constraints outlined in previous sections must be addressed. Fundamental failures of governance and institutional effectiveness must be overcome in order for basic development to take place, and especially for effective strategic adaptation planning and implementation to occur. This will not be easy, given Nepal's long history of institutional upheaval and current political instability, but the country's leaders have little choice if the worst case scenario - continuing perpetual violence and the basic needs of millions in Nepal going unmet - is to be avoided. Due to the ripple effect of such constantly changing institutional structures on the overall effectiveness of the country's national institutions, providing some semblance of stability must be prioritized first and foremost.

Unfortunately, such stability is inherently contingent upon the currently stagnant constitutional development process that will ultimately decide the structure of the national bureaucracy. It is beyond the scope of this paper to advocate specific constitutional structures for creating greater stability, but it is clear that some kind of mechanism, in the constitution or otherwise, is necessary to prevent the constant restructuring of the national ministries and provide stability that will be critical for adaptation and future development. It is also critical to note here that, due to its responsibility, at least in part, for such constant structural changes, the international development community must similarly focus on establishing stability in the country's institutions. The cycle of constantly adopting new faddish development strategies must be broken.

Also critical for adaptation is capacity building at all levels of the bureaucracy so that there is at least a minimal understanding of Nepal-specific impacts and how they will ultimately affect all of the various government ministries and sectors. This is particularly critical for integrating adaptation into the national planning process. There are some indications that the overall effort to increase capacity, especially related to CC science, is already happening, with the WECS moving all climate data processing to one, centralized database, but a much more expansive effort is needed to adequately prepare Nepal's civil leaders for the future. This is especially the case for the Ministry of Agriculture, which must gain a more comprehensive understanding of the likely impacts in order to most effectively target strategic adaptation actions for the most vulnerable regions and crops, including for example, finding adequate substitute crops in some cases. Along these same lines, due to the cross-sectoral and comprehensive nature of many of the impacts of CC, greater intercommunication between ministries and government agencies will be critical to both implementation and integration of national adaptation planning, and also to improve current basic development interventions critical for autonomous adaptation.

Focusing especially on the agricultural sector, there are a number of specific priorities that must be addressed. The most important changes must come in the form of water management. The current National Water Plan (2005) addresses many of these issues, but it has simply not been implemented due to the numerous institutional constraints discussed in this document and so many years of armed conflict. Using this plan as a foundation, water management for adaptation must focus on what will be increasing supply variability, with an emphasis on the following factors:

- Expansion and refurbishment of irrigation and water storage infrastructure;
- Capacity building for more water-efficient cropping practices in local communities including, for example, system of rice intensification (SRI); and
- More research and eventual adoption of climate resilient cropping systems.

These are just some of the major factors that must be addressed for adaptation to ultimately be successful in Nepal. By no means does this document tackle all of the issues involved in what will be a very difficult to implement adaptation process, but it does at least give a general picture of the major issues facing Nepali leaders and stakeholders in responding to the likely impacts of CC. It is clear that unless major institutional constraints are overcome, neither adaptation nor continued development will be effectively carried out. Given this context, it is critical that the various stakeholders in the country as well as the large international donors focus on stabilizing and developing the capacity of the country's institutions if the long-term adaptation effort is to be successful.

REFERENCES

Agrawala, S.; Raksakulthai, V.; van Aalst, M.; Larsen, P.; Smith, J.; Reynolds, J. 2003. *Development and climate change in Nepal: Focus on water resources and hydropower*. Environment directorate, Development Co-operation Directorate, Organisation for Economic Co-operation and Development.

Auffhammer, M.; Ramanathan,V.; Vincent, J. R. 2006. Integrated model shows that atmospheric brown clouds and greenhouse gases have reduced rice harvests in India. *PNAS* 103(52): 19668-19672.

Bates, B. C.; Kundzewicz, Z.W.; Wu, S.; Palutikof, J. P. Eds. 2008. Climate change and water. Technical paper of the Intergovernmental Panel on Climate Change. Geneva: IPCC Secretariat. 210p.

Bajracharya, S. R.; Mool, P. K.; Shrestha, B. R. 2007. *Impact of climate change on Himalayan glaciers and glacial lakes: Case studies on GLOF and associated hazards in Nepal and Bhutan*. Kathmandu, Nepal: International Centre for Integrated Mountain Development (ICIMOD).

Bhutiyani, M. R.; Kale, V. S.; Pawar, N. J. 2010. Climate change and the precipitation variations in the northwestern Himalayas: 1866–2006. *International Journal of Climatology* 30(4): 535-548.

CIA (Central Intelligence Agency). 2010. The World Factbook. Available at www.cia.gov/library/publications/the-world-factbook/geos/np.html (accessed on August 24, 2010).

Cruz, R. V.; Harasawa, H.; Lal, M.; Wu, S.; Anokhin, Y.; Punsalmaa, B.; Honda,Y.; Jafari, M.; Li, C.; Huu Ninh, N. 2007. Asia. *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.; Canziani, O. F.; Palutikof, J. P.; van der Linden, P. J.; Hanson, C. E. eds. Cambridge, UK: Cambridge University Press. 469–506pp.

DST (Desakota Study Team). 2008. *Re-imagining the rural-urban continuum: Understanding the role ecosystem services play in the livelihoods of the poor in desakota regions undergoing rapid change*. Research Gap Analysis prepared by the Desakota Study Team (DST) for the Ecosystem Services for Poverty Alleviation (ESPA) Program of Natural Environment Research Council (NERC), Department for International Development (DfID) and Economic and Social Research Council (ESRC) of the United Kingdom. Nepal, Kathmandu: Institute for Social and Environmental Transition (ISET).

Dhungel, S. pers. comm. Senior Divisional Engineer, Water and Energy Commission Secretariat. Personal Communication, July 6, 2009.

Eriksson, M.; Jianchu, X.; Shrestha, A. B.; Vaidya, R. A.; Nepal, S.; Sandstrom, K. 2009. *The changing Himalayas – Impact of climate change on water resources and livelihoods in the Greater Himalayas*. Kathmandu, Nepal: International Centre for Integrated Mountain Development (ICIMOD).

FAO (Food and Agriculture Organization of the United Nations)-UNDP (United Nations Development Programme). 2003. *Nepal: Agricultural policy and strategies for poverty alleviation and food security*. Available at www.fao.org/docrep/008/ae898e/ae898e00.HTM (accessed on July 20, 2009).

GoN (Government of Nepal). 2010. Nepal - Crop and food security update: Summer crop 2009/2010. Joint report, February 2010. Ministry of Agriculture and Cooperatives and World Food Programme. Available at www.reliefweb.int/rw/rwb.nsf/db900SID/SKEA-85BF8L?OpenDocument (accessed on August 24, 2010).

IPCC (Intergovernmental Panel on Climate Change). 2007. *Climate change 2007: The physical science basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K. B.; Tignor, M.; Miller, H. L., eds. Cambridge and New York: Cambridge University Press.

ISET (Institute for Social and Environmental Transition). 2008. *From research to capacity, policy, and action: Enabling adaptation to climate change for poor populations in Asia through research, capacity building and innovation*. Report from the adaptation study team to the International Development Research Center, coordinated by ISET. Kathmandu, Nepal: ISET.

Karkee, K. 2004. *Land degradation in Nepal: A menace to economy and ecosystems*. Sweden: Lund University.

Kayastha, R. N.; Pant, D. 2001. *Institutional analysis for water resources management in East Rapti River Basin, Nepal*. Report prepared for the Regional Study on Development of Effective Institutions for Water Management. Colombo, Sri Lanka: International Water Management Institute.

Kundzewicz, Z. W.; Mata, L. J.; Arnell, N. W.; Döll, P.; Kabat, P.; Jiménez, B.; Miller, K.; Oki, T.; Sen, Z.; Shiklomanov, I. A. 2007. Freshwater resources and their management. In *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry, M. L.; Canziani, O. F.; Palutikof, J. P.; van der Linden, P. J.; Hanson, C. E. eds. Cambridge, UK: Cambridge University Press, 173-210p.

Liu, X.; Chen, B. 2000. Climatic warming in the Tibetan Plateau during recent decades. *International Journal of Climatology* 20: 1729–1742.

HMG (His Majesty's Government). 2001. Ministry of Population and the Environment. Nepal's State of the Environment (Agriculture and Forests). His Majesty's Government. Available at www.unpei.org/PDF/Nepal-State-of-Environment-Report -2000.pdf (accessed on August 24, 2010).

HMG. 2005. Water and Energy Commission Secretariat. National Water Plan Nepal. Nepal: His Majesty's Government.

McSweeney, C.; New, M.; Lizcano, G. 2008. UNDP climate change country profiles: Nepal. Available at http://country-profiles.geog.ox.ac.uk (accessed on June 20, 2010).

IRIN (Integrated Regional Information Network). 2008a. *Nepal: Agricultural reform "would boost food security."* July 10, 2008. Available at www.irinnews.org/Report.aspx?ReportId=79179 (accessed on July 7, 2009).

IRIN. 2008b. *Nepal: Humanitarian country profile*. April, 2008. Available at www.irinnews.org/country.aspx?Country Code=NPA&RegionCode=ASI (accessed on July 5, 2009).

IRIN. 2008c. *Nepal: Strikes and blockades hitting livelihoods*. August 8, 2008. Available at www.irinnews.org/report.aspx?ReportID=79709 (accessed on July 5, 2009).

MoF (Ministry of Finance). 2007. Economic Survey. Ministry of Finance, Government of Nepal, Kathmandu, Nepal.

NCVST (Nepal Climate Vulnerability Study Team). 2009. *Vulnerability through the eyes of the vulnerable: Climate change induced uncertainties and Nepal's development predicaments*. Institute for Social and Environmental Transition (ISET), Nepal. Kathmandu, Nepal: Nepal Climate Vulnerability Study Team (NCVST).

Ramanathan, V.; Agrawal, M.; Akimoto, H.; Aufhammer, M.; Devotta, S.; Emberson, L.; Hasnain, S. I.; Iyngararasan, M.; Jayaraman, A.; Lawrance, M.; Nakajima, T.; Oki, T.; Rodhe, H.; Ruchirawat, M.; Tan, S. K.; Vincent, J.; Wang, J. Y.; Yang, D.; Zhang, Y. H.; Autrup, H.; Barregard, L.; Bonasoni, P.; Brauer, M.; Brunekreef, B.; Carmichael, G.; Chung, C. E.; Dahe, J.; Feng,Y.; Fuzzi, S.; Gordon,T.; Gosain, A. K.; Htun, N.; Kim, J.; Mourato, S.; Naeher, L.; Navasumrit, P.; Ostro, B.; Panwar, T.; Rahman, M. R.; Ramana, M. V.; Rupakheti, M.; Settachan, D.; Singh, A. K.; St. Helen, G.; Tan, P. V.; Viet, P. H.; Yinlong, J.; Yoon, S. C.; Chang, W.-C.; Wang, X.; Zelikoff, J.; Zhu, A. 2008. *Atmospheric Brown Clouds: Regional Assessment Report with Focus on Asia*. Nairobi, Kenya: United Nations Environment Programme. Available at www.unep.org/pdf/ABCSummaryFinal.pdf (accessed on August 23, 2010).

Regmi, R. R. 2008. Deforestation and rural society in the Nepalese Terai. *Occasional Papers in Sociology and Anthropology* 4: 72-89.

Smit, B.; Burton, I.; Klein, R. J. T.; Wandel, J. 2000. An anatomy of adaptation to climate change and variability. *Climate Change* 45(1): 223-251.

Stads, G-J.; Shrestha, H. K. 2008. Agricultural Science &Technology Indicators (ASTI) country brief: Nepal. July, 2008. Available at www.asti.cgiar.org/nepal (accessed on July 5, 2009).

Subel, B. 2009. "*Late monsoon brings fears of food shortages in Nepal*." The Khaleejtimes. July 5, 2009. Available at www.khaleejtimes.com/DisplayArticle08.asp?xfile=data/international/2009/July/international_July815.xml&section=international (accessed on July 24, 2009).

UNEP (United Nations Environment Programme). 2008. *Freshwater under threat South Asia: Vulnerability assessment of freshwater resources to environmental change*. Available at www.roap.unep.org/pub/ (accessed on July 5, 2009).

UNICEF (United Nations Children's Fund). 2010. Information by country, statistics, Nepal. Available at www.unicef.org/infobycountry/nepal_nepal_statistics.html (accessed on June 10, 2010).

Watkins, K. 2008. *Fighting climate change: Human solidarity in a divided world*. Human Development Report 2007/2008. United Nations Development Programme. Available at http://hdr.undp.org/en/reports/global/hdr2007-2008/ (accessed on July 30, 2009).

WECS (Water and Energy Commission Secretariat). 1999. Basin wise water resources and water utilization study of the Koshi River Basin. Water and Energy Commission Secretariat (WECS), Government of Nepal.

WFP (World Food Programme). 2009. *Winter drought worsens food insecurity in Nepal*. Available at www.wfp.org/news/news-release/winter-drought-worsens-food-insecurity-nepal (accessed on July 5, 2009).

World Bank. 2009a. *Nepal: Priorities for agriculture and rural development*. Available at http://go.worldbank.org/D9M3ORHVL0 (accessed on July 2, 2009).

World Bank. 2009b. *Shared views on development and climate change*. Available at http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/0,,contentMDK:22038355~pagePK:146736~piPK:146830~theSitePK:223547,00.html (accessed on August 23, 2010).

World Bank. 2010. Open Data, Nepal. Available at http://data.worldbank.org/country/nepal (accessed on June 10, 2010).

Zickfeld, K.; Knopf, B.; Petoukhov, V.; Schellnhuber, H. J. 2005. Is the Indian summer monsoon stable against global change? *Geophysical Research Letters* 32: L15707.

IWMI Working Papers

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Related Publications

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www.iwmi.org/Publications/IWMI_Research_Reports/PDF/PUB135/RR135.aspx

Evans, A.; Jinapala, K. (Eds.). 2010. ***Proceedings of the National Conference on Water, Food Security and Climate Change in Sri Lanka, BMICH, Colombo, Sri Lanka, 9-11 June 2009. Vol. 2. Water quality, environment and climate change***. Colombo, Sri Lanka: International Water Management Institute (IWMI). 174p.

www.iwmi.org/Publications/Other/PDF/SLWC_Volume-2-Latest.pdf

Johnston, R. M.; Hoanh, C. T.; Lacombe, G.; Noble, A.; Smakhtin, V.; Suhardiman, D.; Kam, S. P.; Choo, P. S. 2010. ***Rethinking agriculture in the Greater Mekong Subregion: how to sustainably meet food needs, enhance ecosystem services and cope with climate change***. [Summary report]. Colombo, Sri Lanka: International Water Management Institute (IWMI). 26p.

www.iwmi.org/Publications/Other/PDF/Summary-Rethinking_Agriculture_in_the_Greater_Mekong_Subregion.pdf

McCartney, M.; Smakhtin, V. 2010. ***Water storage in an era of climate change: addressing the challenge of increasing rainfall variability***. Blue paper. Colombo, Sri Lanka: International Water Management Institute (IWMI). 14p.

www.iwmi.org/Publications/Blue_Papers/PDF/Blue_Paper_2010-final.pdf

Zomer, R.; Trabucco, A.; van Straaten, O.; Bossio, D. 2006. ***Carbon, land and water: a global analysis of the hydrologic dimensions of climate change mitigation through afforestation/reforestation***. Colombo, Sri Lanka: International Water Management Institute (IWMI). 38p. (IWMI Research Report 101)

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