# ECONOMIC IMPACT ASSESSMENT OF CLIMATE CHANGE IN KEY SECTORS IN NEPAL

**Study Supported by**

Climate & Development Knowledge Network

# Study Inception Report

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Integrated Development Society Nepal

IDS-Nepal

PRACTICAL ACTION Consulting

Global Climate Adaptation Partnership

This project, Economic Impact Assessment of Climate Change in Key Sectors in Nepal, is being undertaken at the request of the Government of Nepal, and is supported by Climate and Development Knowledge Network (CDKN). This project originated to address the target as included in the Climate Change Policy 2011: Assessment of losses and benefits from climate change in various geographical areas and development sectors by 2013.

The work is led by Integrated Development Society (IDS), Nepal, working with Practical Action Consulting Limited (PAC), Nepal and Global Climate Adaptation Partnership (GCAP) in the UK.

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## Acronyms:

| | |
|---|---|
| ADB: | Asian Development Bank |
| AEZ: | Agro-ecological Zone |
| CANSA: | Climate Action Network South Asia |
| CBS: | *Central Bureau of Statistics* |
| CCD: | Climate Compatible Development |
| CDKN: | Climate and Development Knowledge Network |
| COP: | Conference of Parties |
| CSAG: | Climate Systems Analysis Group |
| DFID: | Department for International Development |
| DHM: | Department of Hydrology and Meteorology |
| EACC: | Economics of Adaptation to Climate Change |
| FAO: | Food and Agriculture Organization |
| FF: | Financial flow |
| GCAP: | Global Climate Adaptation Partnership |
| GDP: | Gross Domestic Product |
| GFDRR: | Global Facility for Disaster Reduction and Recovery |
| GLOF: | Glacial Lake Outburst Flood |
| GoN: | Government of Nepal |
| ICIMOD: | International Centre for Integrated Mountain Development |
| IDS: | Integrated Development Society Nepal |
| IF: | Investment flow |
| IFF: | Investment and Financial Flow |
| ISET: | Institute for Social and Environmental Transition |
| LAPA: | Local Adaptation Plans of Action |
| MoA | Ministry of Agriculture |
| MoAC | Ministry of Agriculture and Cooperative |
| MoAD: | Ministry of Agriculture Development |
| MoEn: | Ministry of Energy |
| MoEnv: | Ministry of Environment |
| MoEST: | Ministry of Environment, Science and Technology |
| MoHA: | Ministry of Home Affairs |
| NAPA: | National Adaptation Programme of Action |
| NARC: | *Nepal Agricultural Research Council* |
| NCCKMC: | Nepal Climate Change Knowledge Management Centre |
| NPC: | National Planning Commission |
| NSDRM: | National Strategy for Disaster Risk Management |
| O&M: | Operation and Maintenance |
| OECD: | Organization for Economic Co-operation and Development |
| PAC: | Practical Action Consulting |
| PPCR: | Pilot Project for Climate Resilience |
| RECC: | Regional Economics of Climate Change studies |
| RRN: | Rural Reconstruction Nepal |
| SPCR: | Strategic Programme for Climate Resilience |

| | |
|---|---|
| UNDP: | United Nations Development Programme |
| UNFCCC: | United Nations Framework Convention on Climate Change |
| WECS: | Water and Energy Commission Secretariat |
| WFP: | *World Food Programme* |
| WRS: | Water Resources Strategy |
| WWF: | World Wide Fund for Nature |

# Summary

At the request of the Government of Nepal, the Climate and Development Knowledge Network (CDKN) are funding this study on the '*Economic Impact Assessment of Climate Change in Key Sectors in Nepal*'. The work is led by Integrated Development Society (IDS), Nepal, working with Practical Action Consulting Limited, Nepal and Global Climate Adaptation Partnership (GCAP) in the UK. The primary objectives for this study are to (i) provide headline and sectoral estimates of the impacts and economic costs of climate change for key sectors in Nepal (the agriculture and water sectors), and (ii) to provide a ranking of climate compatible development options to address these risks. This report summarizes the inception phase of the study, including the approach and methods proposed for the implementation phase.

The project has started with a detailed review of existing knowledge and identified gaps. It has found a large number of studies on climate change in Nepal. The study has first reviewed the information on the current climate of Nepal and the impacts and economic costs of existing climate variability. The climate of Nepal varies dramatically across the country, across elevation and climatic zones. These differences lead to a range of risks which necessitate different adaptation responses. The study has also reviewed observational data on recent temperature and rainfall trends which reveals rising (warmer) temperatures over recent decades, but uncertain precipitation trends at national and even regional level. This means early adaptation actions will have to work within a framework of uncertainty, and that a stronger focus will be needed on monitoring to build the evidence base for future action. The links between these current and emerging trends have then been considered in terms of the impacts and economic costs of current climate variability. This reveals that a large proportion of Nepal's GDP is associated with climate sensitive activities (notably agriculture) and that the country is affected by periodic climate extremes (particularly floods) which lead to high economic costs and impact on millions of livelihoods. These translate into a high current adaptation deficit in the country. However, the review reveals that the links between climate, agriculture, water and the economy are complex. Importantly, the review finds there is a need to recognise spatial disaggregation (sub-national) and the differences in agro-ecological and climatic zones across the country when considering current and future climate risks, and therefore adaptation responses.

The study has reviewed the existing climate information for Nepal, looking at a set of statistically downscaled projections and the available global and regional climate model outputs. The projections show continued (and accelerated) warming in future years, but mixed patterns for future rainfall changes, with large variations in the level of change (and sometimes even in the direction of change) between models and locations, especially in relation to future extreme events (intensity and frequency). This reinforces the need to work with multi-model data (rather than central projections) and to recognize this uncertainty rather than ignoring it. It also means iterative strategies will be needed to prepare for uncertain futures, focusing on resilience and robustness, rather than using uncertainty as a reason for inaction.The review has also considered future socio-economic trends, and Government development plans, to investigate future non-climatic drivers, including existing policies and planned activities. Together these form the baseline for current and future analysis, and identify the key plans that require checking for early climate resilience. The analysis of socio-economic trends has revealed strong demographic trends – and population increases - that will affect future risks. The review of Government development policies has shown that there will be major changes to the sectors, which need to be factored into the analysis when developing impacts and a climate compatible pathway. The study will therefore have to align more closely with planned policy than previous assessments, i.e. it will consider risks and develop adaptation strategies that are grounded in current development.

The study has then reviewed the impacts (and economic costs) of future climate change on Nepal. This reveals large differences in the projected impacts, across the range of climate projections and across the different methods used. Much of the focus of the work has been on the longer-term, and there is much less coverage on the short-medium period of most relevance for early adaptation planning. Furthermore, there are large differences in results according to whether studies consider trends only, changes in trends and variability, analysis of future extremes, and cross-sectoral interactions (notably between agriculture and water sectors).

This stresses the need for the study to take account of uncertainty in considering these medium and long-term effects. It necessitates the consideration of the range of model uncertainty, interpreting existing information, as well as undertaking new impact assessment model runs to identify the potential issues of major concern and the associated economic costs. Furthermore, the Asian Development Bank (ADB) are undertaking a regional (five country) study which will include a similar analysis of impacts and economic costs, the results of which this study will build and complement rather than duplicate.

Finally, the review has identified many studies on adaptation, which identify hundreds of options. In the agricultural sector, many of these are based on traditional farm management approaches for agriculture (e.g. changing planting dates, using different crop varieties, increasing fertiliser user and irrigation) though more recent studies emphasize additional techniques focused on sustainable agriculture and climate smart agriculture (e.g. soil and water management, conservation agriculture, agro-forestry, etc.). Similarly, in the water sector, many proposed measures are existing disaster risk reduction / management options (e.g. enhanced meteorological and hydrological capacity, awareness raising, early warning systems, flood management measures). However, the quantitative (and economic) analysis of all of these options has been much less studied. Related to this, there has little consideration of uncertainty and how options perform across the range of possible futures. Finally, recent studies also highlight the issues with barriers to adaptation and the need to take account of climatic and agro-ecological differences, stressing that successful adaptation in Nepal is unlikely to comprise a one-size-fits-all approach across the country. A major gap therefore exists on the quantified analysis of the range of short-medium term measures, their robustness in the face of climate uncertainty, and their regional and sub-national applicability.

Overall, the review confirms the need to consider climate change within an existing pattern of complex changes from climate and other non-climate drivers, and uncertain future effects, which will change (and evolve) over time. As a result the proposed method adopts a more dynamic view of climate change, bringing together a number of evidence lines across different time periods to form an overall view of the impacts, appropriate responses and inter-linkages. The approach starts with the current and looks to the future, and by considering development and sector plans, it grounds the study in national and regional policy. The proposed work plan is split into three work streams:

1 **The costs of current climate variability and extremes in Nepal**. This will provide the analysis of near-term economic costs, including potential impacts from changes in climate variability. For adaptation, the focus will be on addressing short-term climate variability (now and for the next 5 – 10 years) – focused on current and emerging trends, and identifying short-term, "no and low regrets" actions.

2 **The risks to current plans over the short-medium term in Nepal**. This will provide an initial risk screening of the potential impacts of climate change on current plans, i.e. and the associated economic costs. For adaptation, it will focus on building climate resilience (for the next 5-15 years) – focused pragmatically on incorporating climate change into existing plans, using insights from short- and long-term climate risks.

3 **The longer term impacts and economic costs of climate change to Nepal**. This will provide an analysis of the more traditional impacts and economic costs of climate change in key sectors, using information from scenario-based impact assessments and models. For adaptation, the focus will be on planning for medium to long-term climate change (2025 and beyond) – identifying priorities for early action.

These elements will be combined to provide an overall view of the economic costs of climate change in Nepal, that also provides the relevant information for sectoral climate adaptation strategies to respond. As the primary aim of the study is to provide a national level analysis, the study will focus at this level. However, as Nepal's agro-ecological / climatic zones are diverse, the analysis proposes to consider risks in each of the three major agro-ecological/climatic zones (Terai, Hills and Mountains). The proposed sector coverage is for agriculture, including crops, livestock and arable land, and on water, covering irrigation (and the linkage with agriculture), hydropower and water induced disaster.Finally the summary presents the proposed method and steps for the study, along with the proposals for capacity building in country, and stakeholder consultation.

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# Introduction

At the request of the Government of Nepal, the Climate and Development Knowledge Network (CDKN) are funding a study on the '*Economic Impact Assessment of Climate Change in Key Sectors in Nepal*'. The work is led by Integrated Development Society (IDS), Nepal, working with Practical Action Consulting Limited, Nepal and theGlobal Climate Adaptation Partnership (GCAP) in the UK.The study has two mainobjectives:

- First, to provide headline and sectoral estimates of the impacts and economic costsof climate change for the agricultural and water sectors, to provide input to the Government's assessment of losses and benefits from climate change in various geographical areas and development sectors by 2013.
- Second, to provide information on climate compatible development options in these sectors to address these risks, to help the Government strategically start to consider options for climate compatible development pathways.

The project aims to be comprehensive, participatory, and indigenously oriented. A key theme has been to ensure that there is high level of interaction and co-production between the research team and key Government stakeholders, and to build capacity in Nepal for such analysis.

The study is broken down into two main phases:

- An inception phase
- An implementation phase

This report summarizes the findings of the inception phase.

It has undertaken a rapid review to synthesis of the available information on climate change in Nepal. This has included information on the current climate, future climate projections, socio-economic data, vulnerability impacts information, and adaptation. It also proposes the methods and approaches for the main implementation phase of the work, including the communication, stakeholders and capacity building plans.

The inception report is set out as follows. Part 1 provides the review, reporting on existing studies, how these influence the study, and identifying existing gaps. Part 2 describes the proposed conceptual framework, the approaches and methodologies (the method document/method statement) and the consultation proposals and communication plan. It also includes training activities proposed.

# PART 1 REVIEW OF CURRENT KNOWLEDGE

Over recent years, many studies have assessed the potential effects of climate change, and potential adaptation responses in Nepal in the academic and grey literature. A critical part of the inception phase is to review this existing evidence base, to build on existing work and avoid duplication.

The study has undertaken a rapid review of this available information, so as to help develop an appropriate method. This part of the work synthesizes the available information, assesses the potential gaps, and identifies key issues for the methodological proposals and the implementation work plan.

# Baseline Context

Key Summary Points:

- A large proportion of the GDP in Nepal and the livelihoods of its people are in climate sensitive activities, notably agriculture.
- Nepal has abundant water resources, but due to the temporal and spatial distribution of these, there are issues between availability, supply and demand.
- Nepal has recognised the threat of climate change and is implementing climate policies, which provide an important foundation for the study to build on.

## Agriculture

Administratively, Nepal is divided into 5 developmental regions, 14 zones and 75 districts with major three ecological belts: the Terai, Hills and Mountains (Source, MoA). However, 15 sub regions can be identified: Eastern-, Central-, Western- and Mid-western- and Far western-Mountains and the same for the Hills and Terai. There are also five physiographic regions (Terai, Siwalik, Middle Mountains, High Mountains (consisting of the main Himalayas and the inner Himalayan valleys), and the High Himalayas), which mainly dictate Nepalese farming systems.

Nepal's economy is largely based on agriculture. It accounts for around one third of GDP (Figure 1), provides employment to around two thirds of the active population, represents 13% of total foreign trade and is an important component of industrial activity, with the processing of agricultural products (CBS, 2012). Agriculture, including livestock, is the main source of livelihoods for around three quarters of the population. The majority (over 50%) of farmers are small holders cultivating less than 0.5 ha (CBS, 2011).

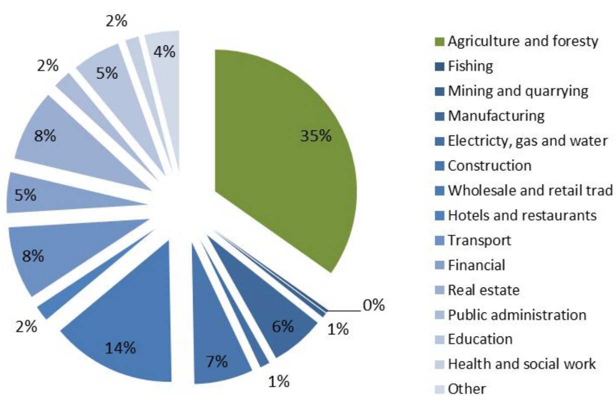



**Figure 1. GDP Split 2011/2012. Source Central Bureau Statistics, 2012.**

Rice, maize, wheat, millet and barley are the major food (grain) crops grown in Nepal. There are, not surprisingly, large differences in agricultural production and crops across the country: Nepal is highly heterogeneous in terms of elevation, climate, water catchments, and agro-ecological zones (Figure 2)[1]. These differences are critical in understanding current and future risks, and designing appropriate adaptation responses.

[1]An AEZ is a homogenous area in terms of bio-physical conditions, including climate, terrain, soil, vegetation and fauna. AEZs are normally defined using a range of metrics, such as elevation, climate (rainfall and temperature) and soil type.


**Figure 2. Agro-ecological Belts of Nepal, Source MoA.**

Nepalese agriculture is predominantly small-scale farming, around half of which is dependent on natural rainfall. 46.5 % of overall cultivated area is irrigated while 69.5 percent of total irrigable area is irrigated, source (MoA, 2012). Rainfall and other climatic factors are therefore critical to crop yields. Historically the sector has been affected by floods, droughts and erratic rainfall. Empirical studiesin recent years indicate that 70 % of the performance of crop production can be explained by the climatic variability linked with the temporal weather conditions (Sherchand et al 2007). As an example, rice requires abundant water (for transplanting) which is sensitive to the onset of monsoon (the pre-monsoon). Irrigation is primarily from farm managed systems (around 75%), with the remainder from agency managed systems. Irrigation development has primarily been in the Terai.

Livestock is also an integral part of the Nepalese farming system, with cattle, goat, sheep and buffalo the major livestock species kept by farmers (DLS, 2009/10).

## Water

Nepal has abundant water resources, with 6000 rivers and rivulets across the nation. The annual surface water availability is around 225 billion $m^3$ (BCM) (WECS, 2011). This provides an extremely large potential resource for hydropower, irrigation, domestic water supply and industrial use, though only around 15 BCM per annum is in use (primarily for agricultural). However, there is a degree of temporal and spatial imbalance between demand and supply. Around 80% of annual rainfall occurs during the monsoon season, from June to September, andaround 78% of the average flow is in the four major basins i.e. Koshi, Gandaki, Karnali, and Mahakali and these snow fed major basins have large water surpluses, while the rain fed medium basins and numerous small southern rivers of the Terai often have deficit flows in the dry season. Nonetheless, there is a huge potential to harness the larger and perennial rivers, and a large volume of water is available in the shallow and deep aquifers, estimated to be 8.8 BCM annually which couldbe used to meet demand for irrigation and domestic water supplies.

Nepal's electricity infrastructure is heavily reliant on hydroelectric power, providing around 90% of the nation's electricity (although overall energy needs are predominantly met from traditional biomass, OECD, 2003; EIA, 2012; WECS, 2011). The current installed capacity of power plants connected to the national grid is about 706 MW of which 652 MW is hydropower capacity (most of the rest is supplied by thermal plants). The technical and economically feasible capacity is extremely large, estimated at around 45,000 MW and 42,000 MW respectively (WECS, 2010). Current electricity demand is higher than available supply, which leads to power cuts and load shedding. Furthermore, Nepal's electricity generation relies mostly on the run-of-river type hydro power plants, and some river flows are insufficient to operate important plants during the dry season. There are plans to address these short-term deficits through expansion, as well as medium term development of the sector as a potential source of growth and exports.

## Climate policy background

The current study builds on the foundation of existing climate studies and plans in Nepal. This includes the 1st National Communication (GoN, 2004), the National Adaptation Programmes of Action (NAPA, GoN, 2010), the Programme of Local Adaptation Programmes of Action (LAPA), the Strategic Program for Climate Resilience (SPCR), and many others. Furthermore, climate related initiatives are included in underlying policies on disaster risk management, and are being mainstreamed into sectoral policies, many of which are implementing early adaptation options. Finally, there are also alarge number of Government, donor and NGO activities – in place and emerging – that are helping to address existing variability, build resilience and adapt to climate change.

It is important for the study to build on these existing studies (and not to duplicate them). Furthermore, these previous studies form a large dataset of implementation practice. The study team hasidentified and reviewed a number of relevant projects during the inception phase, a number of which are discussed below. These will be followed up in the implementation phase to draw together an evidence base of options applied, existing cost information and implementation experience.

# Current Climate Vulnerability in Nepal

Key Summary Points:

- Nepal has an extremely varied climate, reflecting the very large differences in elevation, and the complex regional weather.
- The climate of Nepal is already changing: temperatures have increased over recent decades. There have also been changes in precipitation, though the trends are more complex.
- Nepal already suffers high impacts and economic costs from climate variability and extreme events and it has an existing adaptation deficit.

## Current climate

Nepal is an extremely climatically complex and varied country. This is in part due to its topography, the extraordinary variation in elevation from the plains to the Himalayan high mountains, and the influence of the Himalayan mountain range and the South Asian monsoon. There are four distinct seasons pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February) (GON, 2010).

The climate (and particularly the temperature) significantly varies across the country, due to the strong elevation gradients, from the hot Terai plains (a few hundred metres above sea level) to the cold high mountains, shown below. The highest temperatures occurduring the pre-monsoon period.The lowland regions of Nepal have a warm and humid sub-tropical climate, while the high mountainous regions are cold, and remaining well below zero in the winter (PA, 2009).

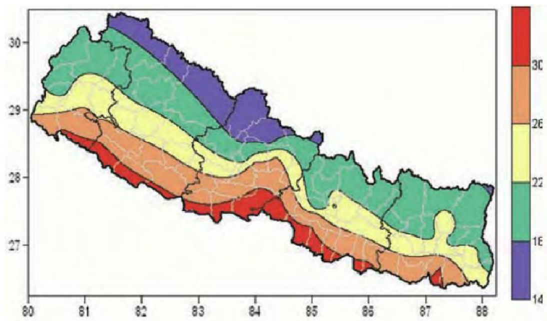



**Figure 3. Spatial variation of mean maximum temperature. Source PA, 2009.**

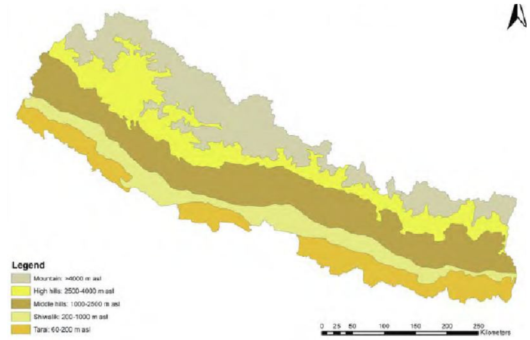



**Figure 4. Elevation. Source PA.**

The mean annual rainfall in Nepal varies dramatically, by area, and perhaps more importantly, by season. The terrain and topography – notably the large mountain systems – have a major impact on rainfall patterns.Average annual rainfall is approximately 1800 mm (GON, 2010), but rainfall is dominated by the monsoon rains, from June to August/September.The monsoon rain is most abundant in the east and gradually declines as it moves towards the west (GON, 2010: PA, 2009). High extreme rainfall is a major source of floods and landslides, as well as soil erosion and sedimentation transfer. Importantly, there is high variability in annual and seasonal rainfall between years (Baidya et al 2007; PA, 2009).

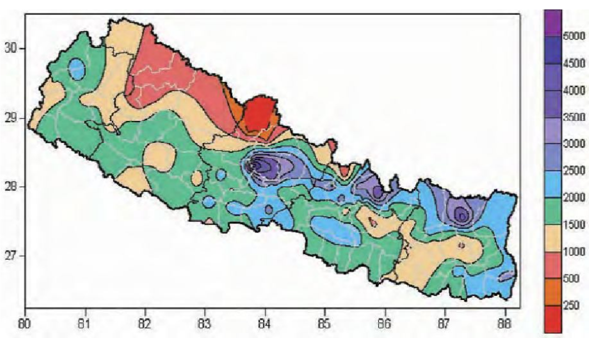



**Figure 5. Annual mean rainfall. Source PA, 2009**

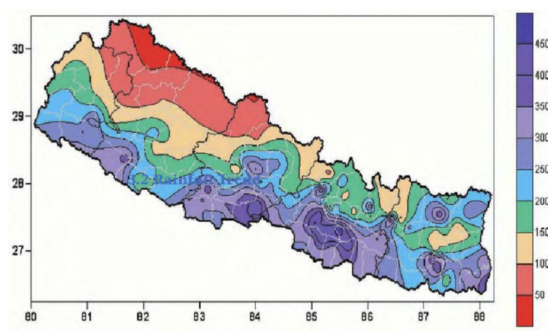



**Figure 6. 24 hours highest rainfall (mm). Source PA (2009)**

## Emerging Climate Trends

In looking towards early adaptation, a crucial question is whether emerging trends that are occurring, i.e. whether the effects of climate change are occurring already, and how these might evolve over the next ten to fifteen years. The study has reviewed the recent trends looking at observational data (including recent trend reviews; Shrestha et. al. 1999; McSweeney et al. Baidya et al 2007; Saraju et. al 2008; PA, 2009; GoN, 2010).

Asia shows a consistent warming trend over the last century. The NAPA(GON, 2010) also reported a trend of observed warmingfor Nepal (though with regional differences).More recent detailed analysis (Practical Action, 2009) looking over a period of 30 years (1976-2005)reports that maximum and mean temperatures are rising. Further increases in temperature are anticipated over the next decade or so, potentially accelerating as climate change signals strongly emerge, though these increases have to be seen against the existing (and dominant) temperature gradients from altitude.

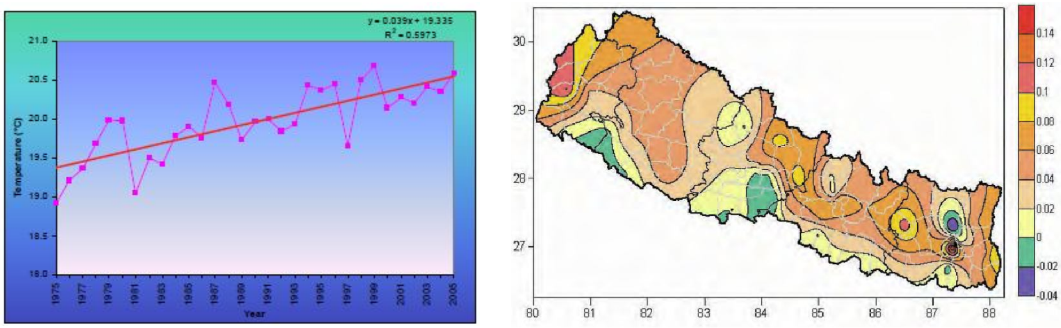



**Figure 7. Annual mean temperature trend Nepal (Baidya et al (2007) and spatial pattern (PA, 2009)**

For rainfall, the situation is more unclear, and there is uncertainty. The NAPA reported that precipitation data does not show any general nationwide trends (though the UNDP country profile (McSweeney et al) reported a trend of decreasing annual precipitation). However there are number of regional precipitation trends and the NAPA reports thatannual precipitation data show a general decline in pre-monsoon precipitation in far- and mid- western Nepal, with a few pockets of declining rainfall in the western, central and eastern regions.Other studies (Baidya et al 2007;Practical Action, 2009) report a change in precipitation over time during the different seasons with some regions show increases and others show decreases. Saraju et. al. (2008) found an increasing trend in the number of extreme precipitation days at the majority of the stations (but particularly for stations below 1500 metres) and highlighted the implications for landslides, flash floods and inundation.

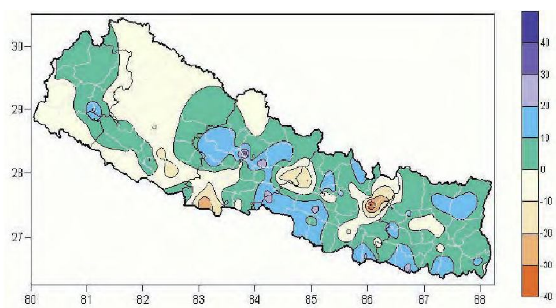


**Figure 8.Annual rainfall trend (mm/year). Source PA, 2009**

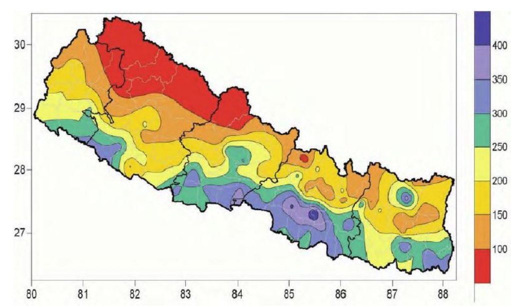


**Figure 9.Extreme rainfall (mm) in 25 year return period (PA, 2009)**

Theanalysis has beenmade difficult because ofthe large variation across the country and inter-annual and inter-decadal variability. The NAPA observes that Nepal's inter-annual variation of rainfall, particularly monsoon precipitation, is so large that observed trends are very uncertain and could be a part of the natural cycle.A key conclusion is that any consideration of emerging trends needs to factor in the very long cycles in the climate (decadal), and should focus on trends at the regional/seasonal level, and that any new analysis is unlikely to resolve emerging trends with certainty.

## The impacts of Climate Variability

A large proportion of Nepal's GDP is associated with climate sensitiveactivities, particularly agriculture. The economy of the country, and the livelihoods of the people, is therefore very dependent on the climate. Climate variability and the frequent occurrence of extreme climate events (particularly floods, but also landslides and occasional droughts) have been a major challenge to the country, infrastructure, the agricultural sector and rural livelihoods (GoN MoHA, 2009). These extreme events have significanteconomic costsat the macro level. There is some data on the historic events in the country, captured through international and local datasets, which can be used to assess theimpacts and associated economic costs of current variability and extremes.

The agricultural sector is dominated by small-holders and rain-fed production, hence it is affected by rainfall variability.Moreover, rainfall and other climatic factors are critical to crop yields, as shown by annual variations in production and growth rates due to these interactions (UNWFP, 2009; Sthapit and Shrestha, 2008; GoN and WFP, 2011). The sector is also affected by extremes such as droughts and floods, landslides, and other weather events (heat stress, hot winds, cold waves, hailstones and snowfall). An important starting point for the study is therefore to look at the current effects of climate, variability and extremes on the sector. At the aggregate level, it is clear that particularly drought events lead to major reductions in production. A number of studies report major effects in particular years, such as the droughts of 2008/9 and 2009/10. The UN WFP (2009) reports that 2009 winter crop harvests were reduced by 40% (Mountain), 25% (Hill), and 10% (Terai) compared to the previous year due to the dry winter, leading to a national decrease in wheat and barley (the two major winter crops) of 15% and 17%, which led to an annual cereal deficit of 133,000 mt despite a excellent summer crop harvests. Indeed, recent years have seen a severe winter drought in 2006 combined with extensive summer flooding, and a 2009/2010 drought event, which is reported to have led to an 11 % loss of rice yields, 7 %loss in wheat and maize, and led to agrain deficit of 400,000 tons (IIED, 2011).

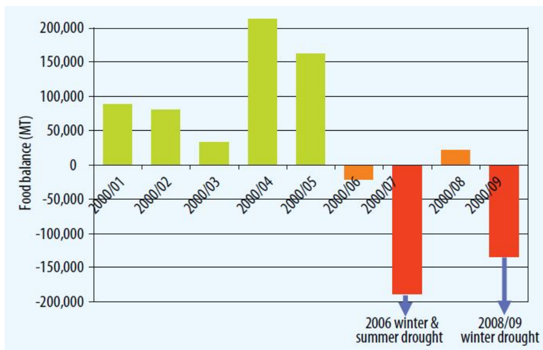



**Figure 10. Overall Nepal Annual Cereal Production Surplus/ Deficit. Source UN WFP (2009)/**

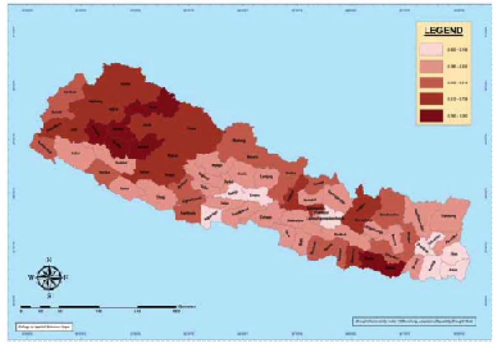
However, there are a much wider set of relationships that link agriculture production to climate – and especially climate variability (GoN, 2004; Sherchand et al, 2007; Malla, 2008; Chapagain, 2011; Sharma and Dahal, 2011; Bastakoti, et al 2011). A number of these have reported existing relationships between rainfall variability and rice and wheat productivity. Many of these relate to important development stages in the pre-monsoon rains, or winter rainfallfor wheat, though some of the difference studies give conflicting relationships for some seasons. Some studies link higher maize production to increased water availability during development (pre-monsoon), but also find high rainfall is detrimental during maturity and harvesting (Nayava et al, 2010). Other studies looking at net farm values find lower rainfall during this season can bebeneficial for early winter crops (such as wheat) as it reduces harvesting losses (Thapa and Joshi, 2010).

There has also been a recent analysis of the links between climate and agriculture, undertaken for IFC as part of the SPCR. This is due to be published during the summer of 2012, and will provide a key input for this study.

Climate variability also affects hydroelectricity production. Hydroelectric plants are dependent on predictable runoff patterns, and thus sensitive to climate variability (OECD, 2003),. They are also subject to the risks of floods and droughts – including risks from Glacial Lake Outburst Floods (GLOFs). Iindeed there was the loss of a multi-million dollar hydropower facility in 1985 due to a GLOF event (OECD, 2003) and more recent loss of micro-hydro plants from floods (Paudyal, 2011).

Water induced disasters are also a major hazard to all sectors. Floods are the major climate related hazard in the country (GoN, 2010), though landslides, drought and fire are also recorded. The mapping of floods, droughts, land-slides and GLOFs is presented in Figure 11 below from the NAPA (GoN, 2010). This shows the differing distribution of risks across the country. The areas considered most vulnerable to floods are Terai plains, mid hills, and high mountains (MoHA, 2009a).Nepal has also experienced frequent droughts in the recent past, andthe most severe extreme droughts in Nepal have occurred during winter (see agricultural discussion above).


Flood Vulnerability Map (Terai). Source NAPA




Drought Vulnerability Map. Source NAPA


Landslide vulnerability map (hill and mountain zone)


GLOF Vulnerability Map. Source NAPA

**Figure11. Vulnerability maps for Nepal.**

Current climate variability and climate induced events, particularly floods including Glacial Lakes Outburst Floods (GLOF)have frequently led toloss of life, damage to property and infrastructure, and major economic losses and costs to the country (GoN MoHA, 2009). Major floods also can lead to large sedimentation deposits, as well as the impact on land and property. These can also affect dam and hydro-reservoirs, which shortens the economic life of projects.

A number of international and national databases,such as the EM-DAT database and Dartmouth flood observatory,record the major floods in the country – with example information below.(EM-DAT, 2012; DFO, 2012).

There are some perceptions with regard to increasing flood events in recent decades. Increases in the population, changing settlement patterns, deforestation and land-use change are likely to be major drivers in flood impacts.

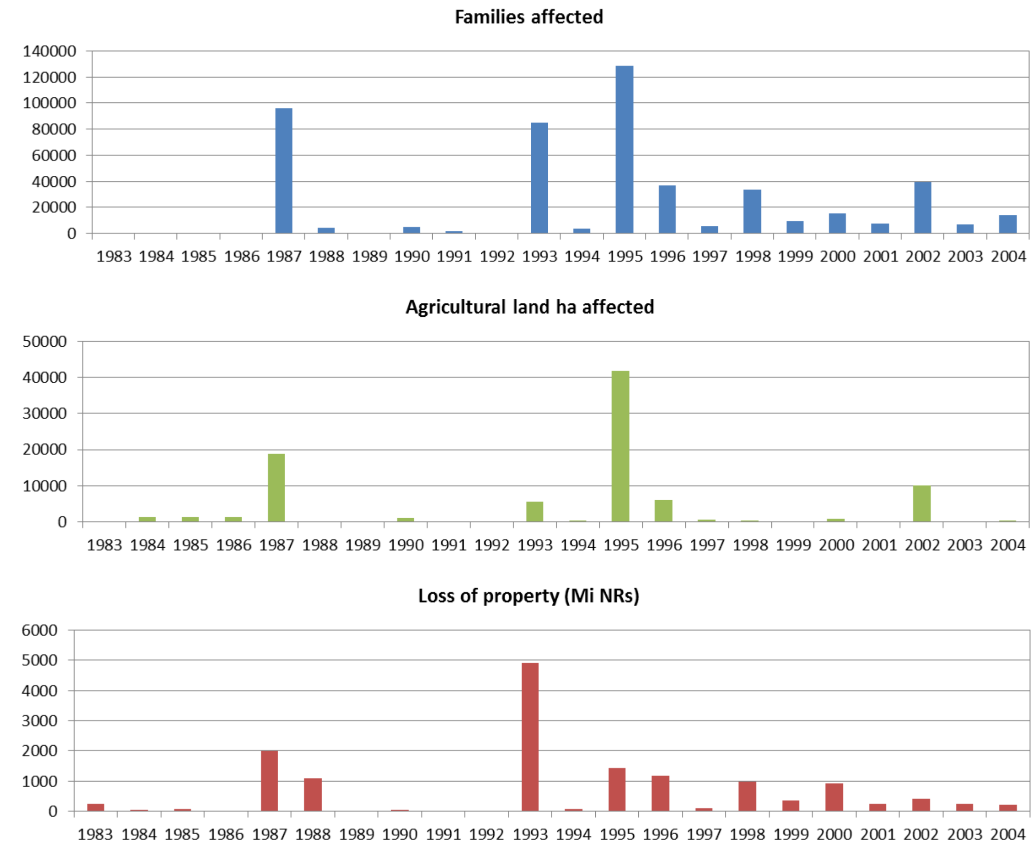



**Figure 12. Annual losses due to floods, landslides and avalanches in Nepal. Source DWIDP, 2004 and MoHA.**

Some studies have already been started to build up a more comprehensive record on the magnitude, frequency and impacts of these floods and other events.The NCVST study (NCVST, 2009) is particularly notable in assessing eight signature events of the recent past that have had impacts consistent with those projected to occur as a consequence of climate change[2]. It also looked at the consequences of these events on an average Nepali household, using paststudies, field observations and bottom-upconsultations. It estimated the burden perhousehold and extrapolated it to the population (e.g. exposed to flood hazards). It then looked at the potential effects of climate change, findingthat climate change could double the damage per household (for floods) and increase the number of households affected by 40% (see Figure 13below).

**Table 5.2: Projected damage to an average Nepali family (in NPR)**

| ELEMENTS | HISTORICAL/CURRENT CONDITIONS | B1R3 CLIMATE CHANGE PROJECTIONS |
|---|---|---|
| Projected basin-wide damages /km² in million rupees | 0.464 | 0.938 |
| Per head | 541 | 1,094 |
| Average household size | 5.21 | 5.21 |
| Per household | 2,813 | 5,581 |

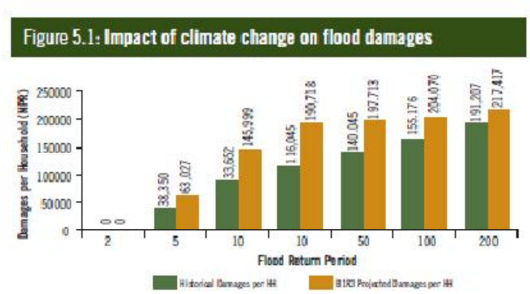
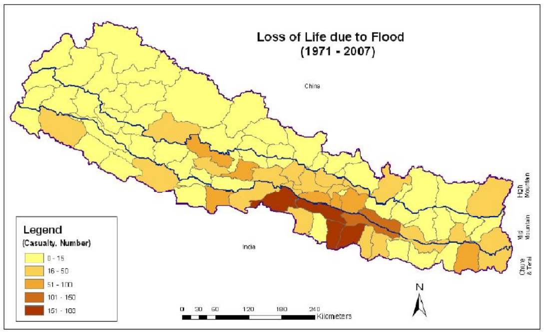
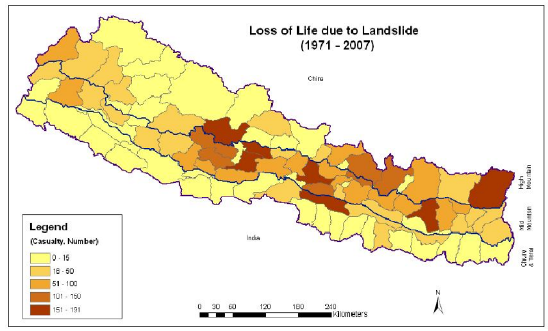



**Figure 13. Damage to family and Impact of Climate Change on flood damages.** Source: NCVST (2009)

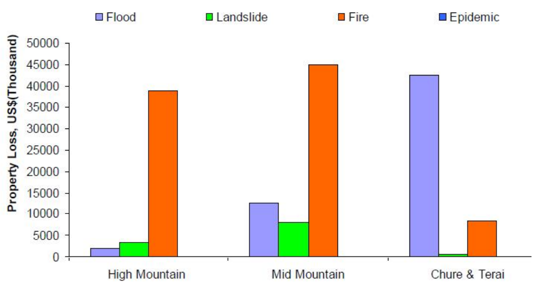
[2]The 1998 Rohini River and other Tarai floods, the 2008 Koshi embankment breach, the 2008 Flooding in Far-West Nepal, the 1993 Mid-mountain cloudbursts and floods, the Recent glacial lake outburst floods, the 2008/2009 Winter drought, the 2009 Forest fires and the 2009 diarrhoea epidemic in the mid-western hills).

The SPCR FinalDocument (GoN: SPCR, 2010)carried out an extensive analysis of historic risks across different parts of the country. Ithas highlightedthe different risks across the Terai (floods), Hills (landslides and floods) and high mountains (GLOF and landslides), and produced a number of maps that show the geographical pattern of historical events (see below), including for loss of life and people affected by different types of climate hazards (floods, landslide, etc.) and property losses (with some splits by area and over time) (Figure 14).




**Hazard maps**



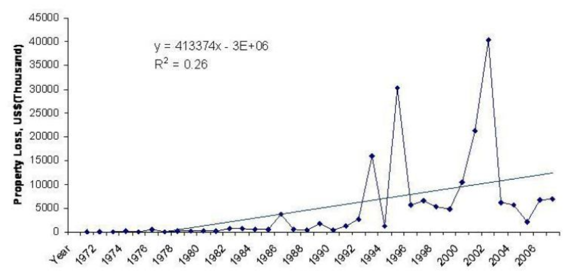




**Figure 14. Property damage ($) (by area and over time)**

Source: SPCR (2010)

A synthesis report on Nepal's major hazards at national and sub-national level has been prepared for the Government with the assistance of the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR), including some hazard assessment and hazard mapping for floods and droughts. Flood hazard maps were developed for seven most frequent flood prone river basins- Rapti, Babai, Bagmati, Narayani, Tinau, Kankai and Kamala. The mapping presents the basins' flood severity in terms of inundation depth and area with respect to the return period of 10 years, 25 years, 50 years and 100 years. Similarly, drought mapping assessments were carried out across the four seasons- winter, pre-monsoon, monsoon and post-monsoon, withhazards classified into moderate, severe and extreme conditions.

The PPCR is also in the process of initiating a major exercise to improve hydro-meteorological systems. It is undertaking detailed sub-basin modeling and hazard and exposure response mapping, and planning to use these for integrated water resources management. It will improve theinformation base significantly.

Overall, it is clear that climate induced events have macro-economic consequences. Individual events oftenhave significant impacts to the economy, with individual events often in excess of $50 million (around 0.3% of GDP)(EN-DAT, 2012). A key conclusion is that Nepal is not adequately adapted to the current climate and therefore has an existing adaptation deficit, which requires urgent and immediate action.

# Climate Model Data and Projections for Nepal

Key Summary Points:

- The projection of future climate change in Nepal is extremely challenging, due to the extreme differences in elevation and the complex regional climate, and any projections remain uncertain.
- Information from global and regional climate models projects strong warming trends for Nepal, though the degree of change varies across scenarios and models.
- The future precipitation regime (average, seasonal, and extremes) is much more uncertain.
- Adaptation policies need to plan for this uncertainty, rather than using this as a reason for inaction.

The analysis of the future impacts and economic costs of climate change requires projections of future climate change, which is produced from climate models. These models use future scenarios (of socio-economics and emissions) to make projections of future changes in temperature, precipitation and other meteorological (and hydro-meteorological) variables over time. The projections are madeusing global climate models that operate at a high level of aggregation.  However, these can be downscaled to regional levels either with statistical downscaling or with regional climate models.  The review has considered the available climate model projections for Nepal.Importantly, there is a significant range of temperature across different scenarios and from different models, which cautions against the use of central trends (or reporting, e.g. with mean values). This can be seen in the figure below, which captures the range of future temperatures across different SRES scenarios and across models – showing that some models project an increase in average temperature in excess of 5 °C by 2080 (Figure 15).

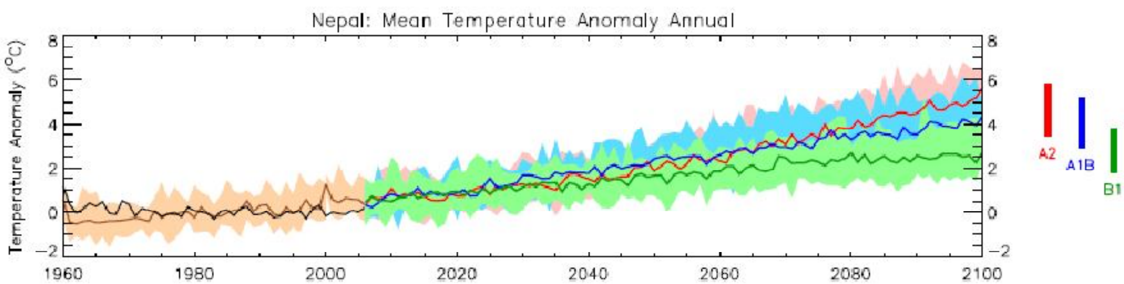



**Figure 15. Trends in annual mean temperature for the recent past and projected future simulated by 15 models for each emissions scenario (McSweeney et al)**

Somemodels projecta likely increase in annual precipitation over the country, though considerable caution is needed in interpreting this finding. The increase in rainfall is primarily associated with increased rainfall during the monsoon season, and further, the models indicate increases in the proportion of total rainfall that falls in ‘heavy’ events.  McSweeney et al (2011) reporta similar variation across scenarios and model projections, indicating changes between -30% and +100% (Figure 16).

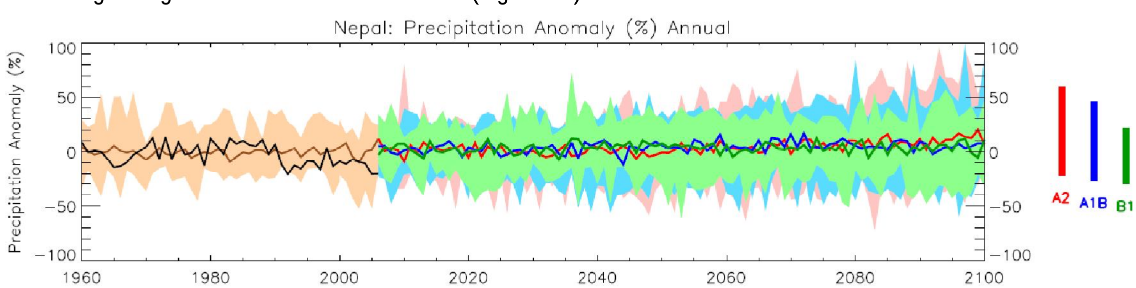



**Figure 16. Trends in annual mean rainfall for the recent past and projected future** simulated by 15 models for each emissions scenario.  % anomaly (McSweeney et al)

This is a critical finding for the study. There are a range of future emission profiles, ranging from low to high levels, and many climate models available. These give very different results, even for variables such as average temperature. For precipitation, the difference is often even in the sign of change (+/-). An important part of the review has therefore been to consider the breadth of available projections, and interpret the information, rather than reporting examples from one or two models. These differences caution against the use of Global Climate Model data, especially given the elevation and climatic zones across Nepal. However, similar differences emerge with downscaled projections.

## Downscaled Projections

The study has considered two alternative approaches for producing downscaled data - empirical (statistical) downscaling and Regional Climate Model (RCM) outputs. An analysis of statistically downscaled data (derived from using station meteorological data) is presented below, from the University of Cape Town archive (A2 scenario for the 2040-2060 time period, UCT, 2012). This considers around 9 models, downscaled to individual met stations (Figure 17). The climate change projections for Kathmanduare shown in the box below (for 2040-2060 period for the A2 scenario). These show broadly consistent trends for temperature, but very complex and uncertain projections for precipitation. The downscaled data shows even greater variation when the wide range of climatic zones in Nepal is considered. This is shown in Figure 18, which plots downscaled mid-century projections for different stations across Nepal, noting that each hasa very different existing climate.

***TEMPERATURE***. All the climate projections show increasing temperature (average and extremes), though the level of increase varies slightly across the models. The figure below shows the monthly daily maximum temperature for the 2040 – 2060 time period (A2 scenario). The top box shows the absolute modelled temperature, with the current climate shown in grey, and the future climate with climate change shown in pink. The bottom box shows the increase from the current (modelled) climate in blue. In both cases the width of the lines represents the range across the different models.

**RAINFALL**. The projections of future rainfall are more complex. The projections show changes in monthly rainfall forKathmandu, showing how the changes vary across the models for the 2040 – 2060 time period (A2). The top box shows the absolute modelled precipitation, with the current climate shown in grey, and the future climate with climate change shown in red. The bottom box shows the change from the current (modelled) climate in blue. In the bottom graph, the height of the columns represents the span of the different models (with the average line also plotted).

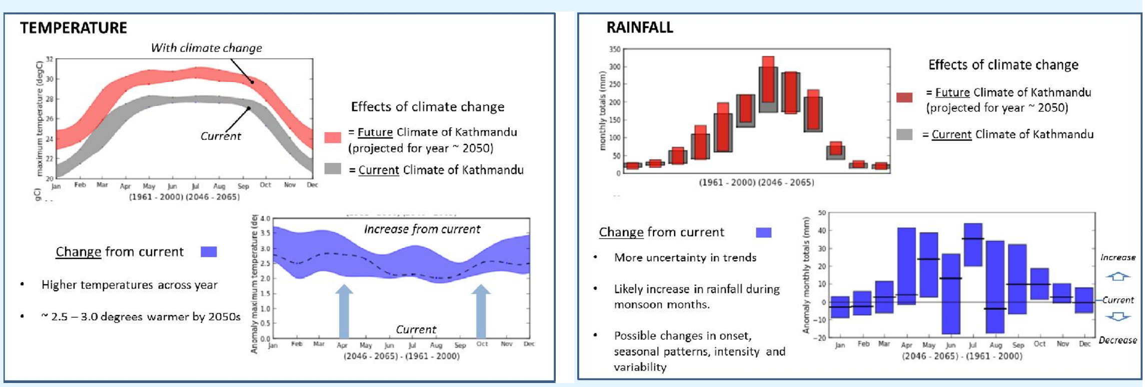



**Figure17. Temperature and Precipitation Projections for Kathmandu (A2, 2050)**

Source of data: Climate Systems Analysis Group (CSAG), University of Cape Town, UCT (2012)

Figure 18 shows the monthly daily maximum temperature and monthly rainfall for the mid-century projections (A2) – for both current and future (top figures) and relative to current (bottom figures), for temperature and precipitations. While the relative changes in temperature are similar across areas, these arise on top of very different baseline climates, and will therefore have very different impacts. The changes in rainfall vary significantly by location, which leads to strong differences in the patterns of seasonal and monthly rainfall, with different precipitation trends in different parts of the country, and different levels of changes, though there is a common theme of uncertainty.

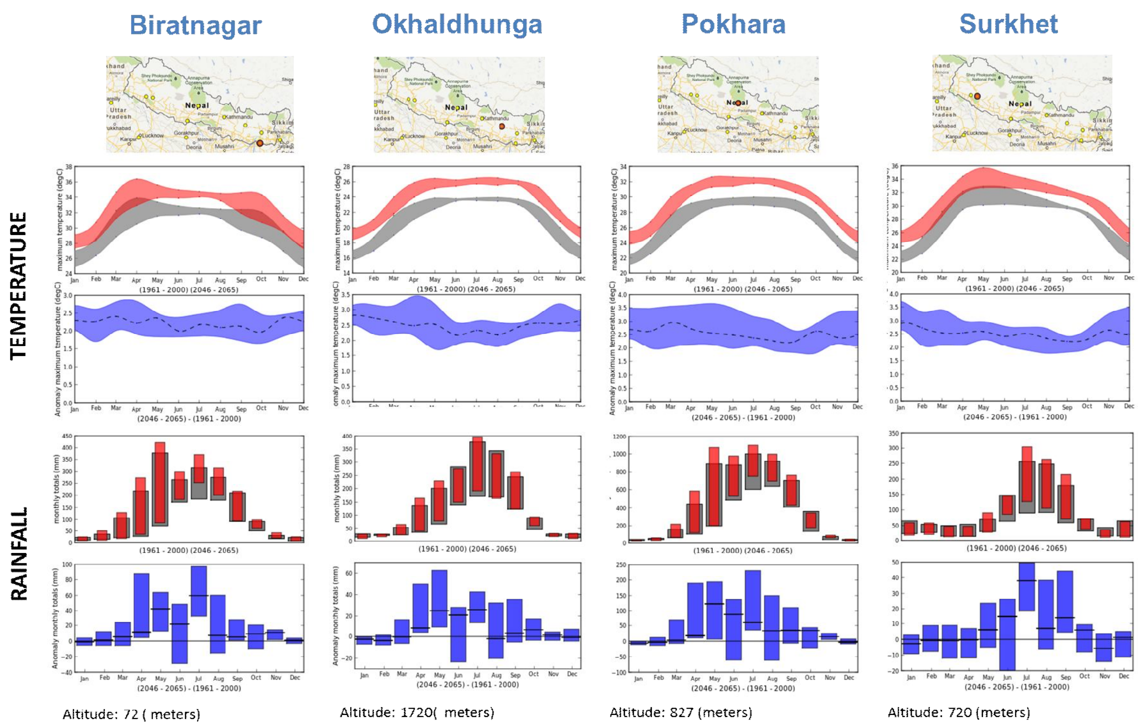



**Figure 18. Monthly daily maximum temperature and monthly rainfall for the mid-century projections (A2) for different sites in the country.**

Source: Climate Systems Analysis Group (CSAG), University of Cape Town, UCT, 2012.

With respect to Regional Climate Models, there have been several families of models applied in Nepal (NCVST, 2009: Karmacharya et al., 2007; GCISC et al. 2009). As an example, the DHM study (Karmacharya et al., 2007) projects warming in all seasons in the mid-21$^{st}$ century (2039-2069) with the warming in the northern part over the high Himalayas being higher than that in the southern part, and highest in the winter and lowest in the pre-monsoon season in both the east and west Nepal. The annual mean temperature was projected to rise in the range of 1.7$^{o}$C in the southern region of the country to 2.5$^{o}$C in the northern region. It also projected a decrease in annual precipitation in large parts of the country, mainly in the eastern and southern Nepal (by up to -30%) but no change in precipitation over north central and north-west Nepal, and with varied seasonal changes. A new set of regional climate model runs have recently been produced as part of the DHM climate portal (which has three regional climate model outputs for the A1B scenario) and the 2$^{nd}$ National Communication, which again has a RCM output for the A1B scenario.

While these regional applications are very promising, it is important to highlight that while regional models may start to address the complexities of the local climate, the use of a small number of regional models does not capture model variation, i.e. it is not a substitute for multi-model ensemble analysis – indeed, it can even be counter-productive by giving apparent confidence without capturing the underlying model bias, e.g. whether the model is warmer, wetter, drier, etc..

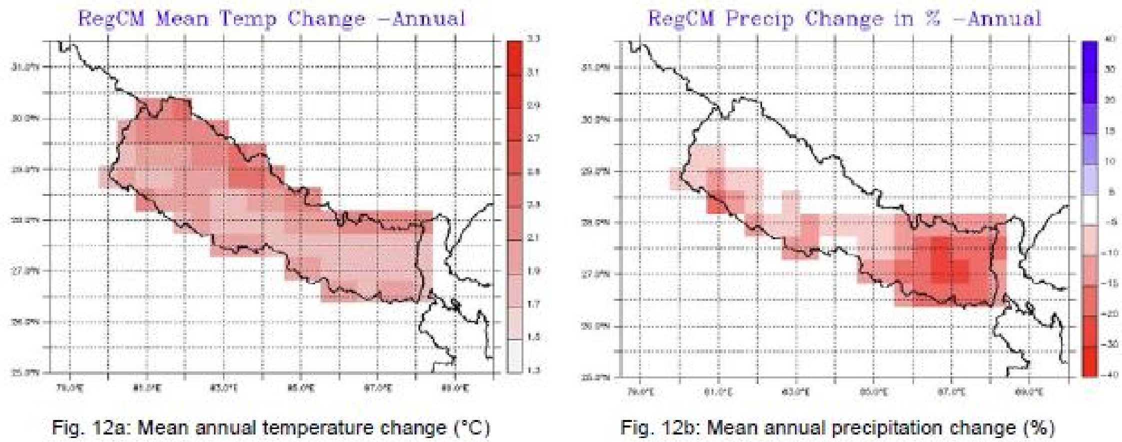



**Figure 19. RCM output for Nepal.** Source:Karmacharya et al., 2007

Furthermore, due to the complex topography, local variations in response to global and regional climate change, particularly for precipitation, are likely to be large and many areas may vary from the regional trend – as highlighted by McSweeney et al, there is a lack of consistency between models in representing monsoon processes. This will contribute to uncertainty in estimates of future precipitation.

Finally, there is the potential for major changes in the longer-term with the monsoon patterns of the region, with the transformation of the monsoon highlighted as one of a number of potential global tipping points (more recently referred to as tipping elements).

Overall, the projections indicate that there is high uncertainty for future rainfall, and even more so for the changes in variability and extremes, and thus broadly for water related impacts and water resources.

The review clearly highlights that for rainfall, variability and extreme events (e.g. floods and droughts), the results from the models differ significantly and there is a need to consider the outputs of a range of models, rather than a single central projection. Indeed, even if new RCM runs emerge, these will not solve the issue of future model projections, because of the range of emission scenarios and range of models, let alone the underlying evidence on some of the more complex effects of climate change on the regional climate from changes in the high mountains. It is essential to recognize this uncertainty, rather than ignoring it, and to plan robust strategies to prepare for uncertain futures, rather than using uncertainty as a reason for inaction.

# Socio-Economic Data and Sector Projections for Nepal

Key Summary Points:

- The future impacts of climate change will be heavily influenced by future socio-economic development.
- It is important when considering climate change impacts – and adaptation responses – to take future these into account.
- There is also a need to build resilience to climate change into development policies.

In considering future vulnerability to climate change, and adaptation responses, a critical step is to consider how socio-economic development might change the country over future decades. This is important because these socio-economic changes – such as population growth, the size of the economy and land-use development - will affect future vulnerability, impacts and adaptation. As an example, future population growth will increase demand for water and for natural resources, and there are existing migration pressures which will affect the sector.

Previous studies show that these future non-climate drivers are as important as climate change in determining future economic costs. Furthermore, failure to take future changes into account assumes that future climate change will take place in a world similar to today. There is also a need to consider how development itself will change future vulnerability, impacts and adaptation. The current and proposed policies and development plans of Nepal will influence future baselines at the national and sectoral level. In many cases development will decrease the vulnerability to climate change (though this is not always the case).

Conversely, climate change might actually affect these wider development objectives, and thus these policies themselves maybe at risk from changing climate trends and future climate change: there is therefore a need to analysethese existing policies in relation to climate resilience.

One of the strongest socio-economic trends is future population growth. The population of Nepal has been rising rapidly, growing from 12 million in 1970 to around 30 million currently (CBS, 2012). Future projections indicatean increase in population to around 35 million by 2020, 40 million by 2030, 43 million by 2040 and 46 million by 2050 (UN, 2012), noting the rate of increase is projected to slow significantly. This growth will increase demand on land-use, natural resources and water.

The majority of the population (83%) is currently rural and mainly relies on agriculture for their livelihoods. However, there have been strong urbanization trends in recent years and the urban population expected to increase to over 20% (to around 7 million people)by 2020 (UN, 2012) –noting that labour migration is a form of coping strategy itself.

The other key socio-economic driver relates to the economy and economic growth. Agriculture remains a large proportion of current GDP (at just over one third) in the future.Annual growth rates have been fairly constant over recent years, but it is highlighted that the growth rate of agriculture fluctuates strongly between years, in part due to the influence of the climate. More recently there has been a strong increase in overseas remittances and these are likely to increase strongly in the future if the present trend continues.

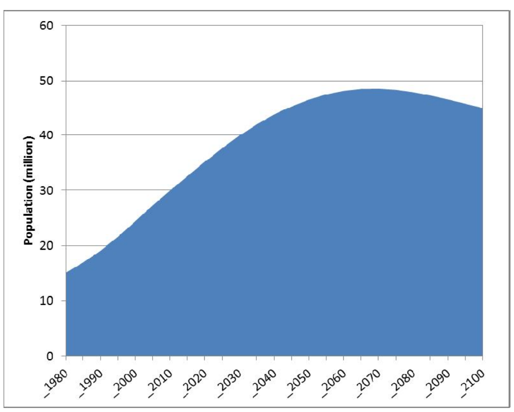



**Figure 20. Population projection to 2100**. Source UN Population Projections.

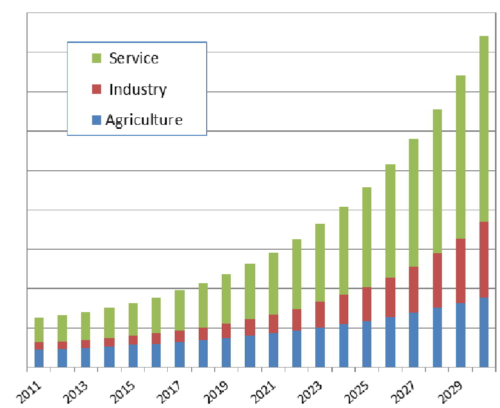



**Figure 21. Real GDP growth and sector split to 2030**. Source Nepal Development Vision 2030

There are short-term national development goals within the Government Three year Plan (2010/11 – 2012/13). This aims to increase the economic growth rate up to 5.5%, with agriculture at 4% and other sectors at 6.4%. The TYP also has introduced the concept of climate resilient planning particularly in the policy and strategy of infrastructure projects (promoting green development, making development activities climate-friendly, mitigating the adverse impacts of climate change, and promoting adaptation).

In agricultural sector, the TYP aims to enhance food security, generate employment and improve thetrade balance through modernization and commercialization, and to increase the production and productivity of agriculture and livestock commodities. Importantly a number of programs are being introduced to advance these goals in the sectors, which are important in relation to the study. The plan also includes sectoral climate change activities. In the water sector, the role of irrigation and hydropower are highlighted, with the objectives to increase irrigation and thus agricultural production and productivity, to protect infrastructure from water induced disaster, and to progress production and distribution of hydropower. A number of policies and strategies are outlined towards these aims, which again, include climate resilient planning.

There is also a longer term Nepal Development Vision (2030), which has the aspiration of becominga middle income country over the next decade and to an upper middle-income country by 2030. This foresees high average annual GDP growth rate (9% during the next decade, and over 10% higher during the following decade), with a structural shift that makes electricity, gas and water one of the prominent sectors, and a key driver for growth from the production of hydropower. Any effects of climate change on hydro generation will therefore affect growth potential. While there is an anticipated move away from the current dominance of agriculture, the sector is still anticipated to drive growth forward, and includes irrigation as one of the drivers, Again there is therefore a strong linkage with climate and other drivers.

In capturing current vulnerability and wider non-climatic drivers, a number of other underlying issues also need to be considered. There are, for example, problems of low soil water and fertility in some regions, and wider issues of the degradation of ecosystems and ecosystem services. The drivers of population and socio-economic changewill potentially increase these pressures. However, many of these issues are already the subject of existing development plans and activities.

The study has reviewed a wider range of existing policies andsectoral plans. Forexample, the Agriculture Perspective Plan (1997-2017)has not taken climate change into account. Similarlythe National Strategy for Disaster Risk Management 2007-2015 (NSDRM), the National Water Resources Strategy (WRS) 2002 and the National Water Plan (NWP) 2005. However some policies and initiatives are already addressing climate change. Of particular note is the fact that climate resilience is already being mainstreamed through the National Planning Commission climate-resilient planning initiative (NPC, 2011).

It is to be notedthat many of these policies already include many of the adaptation options that are discussed in a later section. For example, existing agricultural polices encourage and promote the introduction of flood control methods; improved weather information; etc. It is therefore critical that the current study takes these policies into account. In addition to producing information on applicability, and the effectiveness and costs, these also provide critical information on wider barriers, institutional, acceptability and practical implementation experience on these early adaptation options.

# Climate Impacts Studies inNepal

Key Summary Points:

- Climate change could have potentially large impacts in Nepal in the agricultural and water sectors.
- There are important risks to crop production, potential shifts in agro-ecological zones, and potential effects on livestock, but these vary across the range of climate projections and methods, and have strong spatial differences across the country, that potentially include positive as well as negative effects. =
- Similarly, climate change will have important consequences on the water induced disasters and hydro-electricity generation.

There are now a number of studies, academic papers and reportsthat have assessed the future impacts of climate changein Nepal. Many of these are focused in the agricultural and water sectors, and thus of high relevance to the current study.The study has reviewed these available studies.

The starting point is the extensive work reported in the 1st National Communication (GoN, 2004), and the NAPA (GoN, 2010). The NAPA identified agriculture (and food security), water resources and energy, and climate induced disasters, as three of the six key climate impact areas for Nepal, and also consideredgender and social inclusion as cross cutting themes for the country.

There are studies on the potential effects of climate change and agriculture in Nepal (Sherchand et al, 2007; Malla, 2008; Rai et al; Pokhrel and Pandey, 2011; Nayava et al 2011; Thapa and Joshi, 2010; Pant, 2011; Lama and Devkota, 2009; Bastakoti et al 2011). While the focus is often on crop yields, many studies highlight that a range of potential direct impacts of climate change on agriculture are possible, including effects on cropping seasons and patterns due to change in temperature and rainfall pattern, changes in the suitability of land for different crops as the isothermal lines and temperature andrainfall patterns change, changes to evapotranspiration, photosynthesis, carbon fertilization (positive), changing exposure to floods and extreme events, changes in diseases and pest environment, and possible changes in physical, qualitative and quantitative aspects of other factors of production such as land and soil. It is to be noted that many of these could be positive as well as negative, and effects will vary strongly with location and existing systems. There are also a range of indirect effects.

The main quantified focus to date has been on crop production and two main approaches have been used in the agricultural sector to assess future impacts (and economic costs): crop models and ricardian (econometric) analysis.

There is a significant literature that has applied crop models (agronomic models) to assess the soil-plant-atmosphere components relevant for plant growth and yield, and alsolook at the effects of future climate change on crop productivity (GON, 2004: Sherchand et al, 2007; Rai et al). These have foundmixed results for Nepal, often with a mix of positive and negative effects depending on the degree of change, and the geographical areas considered. Many studies report an increase in crop productivity, especially at modest levels of temperature change (and especially when $CO_2$ fertilization effects are factored in). As an example, early DSSAT modeling in the National Communication (GON, 2004) reports that temperature rise might increase wheat output in the western region of Nepal but could lead to a decline in other regions. Rice yields were also generally anticipated to increase up to a certain temperature level. However, potential decreases in yield were reported for maize (a temperature sensitive crop) particularly in the Terai. Overall, effects have beenstrongly influenced by future $CO_2$ concentrations and $CO_2$ fertilization effects. Moreover, the studies and other literature highlight that the changes in productivity vary not just on temperature but on future precipitation and water availability.

The DHM/APN (Sherchand et al, 2007) study also applied DSSAT. It reports that $CO_2$ concentration increases (in the absence of other effects) would increase crop production (due to fertilization effects). However, varied effects were found across the three crop types and three physiographic regions (Terai, Hill and Mountain) when temperature and rainfall trends were factored into the analysis. For rice, there were broad increases in yields projected across the temperature and rainfall changes, though with a lower relative increase with higher temperature changes in the Terai. For wheat, yields were more varied, with some reductions in yield in the Terai when temperature was factored into account, but favourable changes reported in the mountains. For maize, projected yields declined in the Terai and Hill regions with higher temperatures (though led to positive effects in the Mountains). However, it also highlighted that many of the crops are particularly vulnerable to variability and droughts in key stages of development (particularly pre-monsoon). Overall, the projections were reported to show that Nepal could move from a nation of marginal surplus under a baseline normal scenario to a case where supply and demand only just balanced under the climatic change scenario (assuming no adaptation). Rai et al, using the DSSAT model, looked at rice in Nepal and reported that modest temperature increases (minimum temperature) have positive effects, but above 2°C negative impacts start to arise.

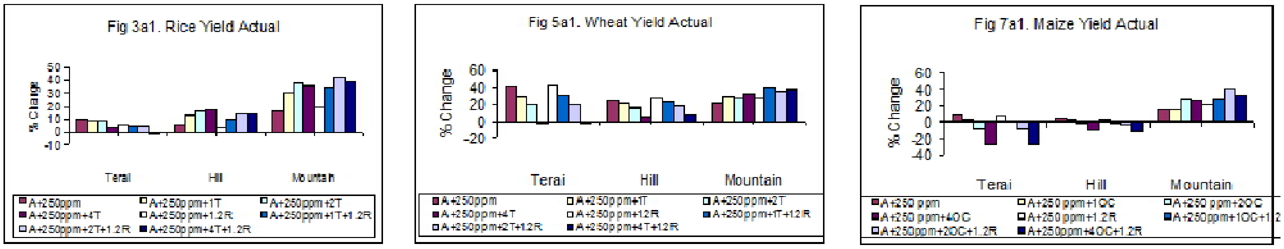



**Figure 22.** Rice, wheat and maize yield at different altitude regimes as influenced by climatic variability. Source Sherchand et al (2007)

There have also been some Ricardian modeling studies, which consider the long-term productivity of land, and consider different influences on land value or farm net revenues, including climatic differences, using cross-sectional data. These can look at how future climate conditions affect these land values or farm net revenues. Thapa and Joshi (2010) apply such a Ricardian approach to Nepal. This identifies existing relationships between net farm income and climate variables. The findings show that these variables have significant impacts on the net farm value per hectare. The study reports that relatively low precipitation and high temperatures during the fall and spring seasons seem to have a positive impact on net farm income: this is thought to be because high precipitation during these periods coincides with the harvesting of major crops such as paddy rice and maize (in fall) and wheat (in spring), and thus increases the risks of damaging crop output during harvest. The study also reported that net farm income is likely to be increased by summer precipitation (enhancing productivity of rain-fed crops), but not by summer temperature. Looking to potential effects of climate change, the study reports that rising temperatures are likely to reduce farm outputs. Marginally increasing precipitation during summer and winter would increase net farm income, but the study concludes that the impact of climate change on agriculture varies with the temperature and precipitation in different climatic zone – and as an example – reports that marginally increasing precipitation would increase farm income in the Hill region, but reduce it in the Terai.Note that these ricardian approaches implicitly include adaptive behavior. Similar approaches have also been used to assess the effects of climate on livestock (Seo and Mendelsohn, 2006), but not in Nepal.

Some reviews also consider that smallholder farmers will bear disproportionately high costs of climate change, thus there may be important distributional effects to the changes seen.There are also important issues in relation to the distribution of effects, particularly by gender and by social group.

Other studies indicated potentially major shifts in agro-ecological zones, however, because of the size and climatic variation across the country and importantly across elevation zones, there is potentially overlap between current and future agro-ecological zones, i.e. future growing seasons similar to today will be found in the country, but not in the same areas.

The existing literature does show that there is a high uncertainly in the effects of climate change on agriculture. Considerable care must be taken in interpreting these results, from both the crop and ricardian studies. Many of these studies do not fully consider the complex issues of rainfall variability and extremes, and studies that do factor these issues andoften come up with different conclusions. Furthermore, the agriculture sector is likely to be adversely affected by the loss of top fertile soil due to soil erosion, landslides, and floods associated with climate change, as well as potential effects such as from changes inpests and disease, that are not captured in the models.

Indeed, future projections of impacts are influenced by crops considered, the climate parameters assessed (single vs. multiple, average vs. variability), the inclusion or exclusion of $CO_2$ fertilization, the method used, and even the specific model (or group using the model). Added on top of this, the complex interactions with water availability and water management, changes to pest and diseases, autonomous farm level adaptation, and emerging policy and development plans, all mean that the future projections of impacts are unclear, and the overall economic costs are compounded, by the influence of relative effects at regional and the global level. This is important because the results of any study – and the parameters considered – influence the adaptation options recommended. As well as different results, the range of studies leads to differing recommendations (or at least a different focus) on where adaptation should focus.

The range of study results - while providing extremely useful information - highlights the uncertainty involved. A key focus of the study will be to consider the outputs from these existing models and studies, as well as undertaking new modeling analysis. A critical issue related to this will be to consider uncertainty, and thus to build up scenarios of possible future changes over time, across multiple drivers, considering the range of potential outcomes and major effects (including thresholds). It is also highlighted that there are strong cross-sectoral linkages, particularly with the water sector, which need to be factored into account in developing a holistic adaptation programme.

There is relativelyless information availableon the potential effects of climate change on livestock. The studies and reviews available (Pokhrel and Pandey, 2011, Sherpa, et al. 2009) indicative a combination of possible effects, either from direct impacts (heat stress) or from indirect effects associated with vector borne disease, impacts on pasture or forage production, climate variability and water availability or hazards risks, and highlight potential increases in production costs and/or declining productivity. The studies identify that yaks might be particularly vulnerable to climate change, due to the fact they are acclimatized to colder temperature, and are sensitive to high temperatures, with effects potentially exacerbated by herding practices.

A number of studies have also assessed the potential changes in the water sector in Nepal. The changes in water are strongly linked to the changes in precipitation projected by the climate model projections, but also include a much large number of factors such as the effects on snow fall and melt, glacier coverage, evapo-transpiration, etc. as well as changes to demand.A number of watershed simulation models as well as rainfall-runoff inundation models have been applied, and there has been some (limited) application of water management models, as well as trend analysis.

A number of studies that look at temperature increases and the effects on glaciers/deglaciation (Rees et al, 2004; Chaulagain, 2006) indicate that climate change could increase river flows in the short-term, by enhancing glacier and snow melt, but that in the longer-term, river flows might reduce. Rees et al (2004) looked at the Hindu Kush Himalaya and) highlight that effects will vary strongly across different catchments and regions: highly glaciated catchments, where melt-water contributes significantly to the runoff, appeared to be the most vulnerable to deglaciation, and these might even reduce some river flows (in terms of melt water) within the next few decades. However, additional changes in precipitation from climate change, temperature and other climatic factors need to be factored into these assessments, as well as the potential changes in demand. Rees et al (2004) report that precipitationwill have a major influence on how the deglaciation impacts varyregionally.

In terms of rainfall and river discharge, in line with the climate models, there are strong differences by season, and high uncertainty across the models that translate into projections of water availability. These are further exacerbated due to the complexity of the Nepalese monsoon (thus even downscaled models have high uncertainty of future trends). Some studies (e.g. GoN, 2004) report potential increases in river discharge associated with increased monsoon rainfall, also noting that the increase in extreme precipitation would be a factor in increasing flood risks. NDRI/ICHARM (2012), using a Rainfall Runoff Inundation (RRI) model, project that precipitation frequency will increase in the near future due to climate change, with an increase in intensity that will increase extreme (flood) events in thelower West Rapti River Basin, leading to increased household damage and agricultural losses. Importantly, they identify that the most affected villages from increased risks are also the areas which are most socio-economically disadvantaged.

Sharma and Shakya (2006) assessed potential changes from emerging climate change trends in the Bagmati River basin, which is interesting due to the current water supply deficit. The study reports a trend of reduced mean yearly flow and monsoon season flow in the Bagmati River, and highlights the effects of continued trends on hydro-power production. The study also reports that the magnitude of floods is decreasing but the frequency and duration are increasing.There are also possible issues of increasing demand and reduced supply water (e.g. Downing et al, 2012) between India and Nepal, and that given underlying demand trends, any changes from future climate change could be important.

Such studies show the importance of local information and conditions, and analysis really needs to be undertaken at the catchment level, and to consider subsequent impacts and economic costs, this needs to extend to the analysis of demand as well as supply and availability, though previous applications of water management models (e.g. in the Tinau) have found the variability in the mountain context makes such assessments very uncertain.

Importantly, there is a major study which is undertaking an assessment of the impacts and economic costs of Nepal, as part of a five country ADB study. This is due to be completed within the next year and it is important for the study to avoid duplication with this study. The second national communication report will also give further information on national scenarios and provide additional climate model outputs.

Overall, the studiesin both the agriculture and water sector reveal large difference in the possible future impacts, partly related to the range across the climate projections (above), but also due to the methods used. Much of the focus of the work has been on longer-term effects (2050 and beyond), and there is less coverage of the short-medium term of most relevance for initial resilience planning. The review also highlights that there is considerable uncertainty, given underlying information on the climate model projections, and subsequent impacts taking into account the range of possible effects, especially when acting in combination.

# Adaptation

Key Summary Points:

- There are an extremely large number of potential options for the agricultural and water sectors in Nepal.
- A key focus in considering and prioritising these options is to consider the strong spatial differences across the country, for example, recognising that options suitable for the Terai will differ to the Mountains.
- The consideration of uncertainty is critical: there is a need to develop options within a framework of decision making under uncertainty, as part of an iterative process.

Many studies have highlighted possible adaptation options for Nepal. These have been recommendedby national processes, such as the NAPA and other studies. This study has reviewed these reports and studies and found that the full list runs to hundreds of adaptation options and interventions, including a mix of technical, non-technical and capacity building options, insurance based schemes and market-based instruments, targeted at public and private sector, and from national down to household level.

As highlighted earlier, many potential options are already being introduced or tested, as part of existing sectoral plans, which provides a rich source of information for the study.

The NAPA (GoN, 2010) identified a number of adaptation measures. An initial long-list was prioritizedto produce a list of 9 options with an estimated budget of $350million. Five of these are particularly relevant for this study.

- Promoting community-based adaptation through integrated management of agriculture, water, forest and biodiversity sector
- Building and enhancing adaptive capacity of vulnerable communities through improved system and access to services related to agricultural development
- Community-based disaster management for facilitating climate adaptation
- GLOF monitoring and disaster risk reduction
- Empowering vulnerable communities through sustainable management of water resources and clean energy supply

A number of papers and studies have considered adaptation options for agriculture in Nepal (IIED, 2011; Sherchand et al, 2007; Malla, 2008; Rai et al; Pokhrel and Pandey, 2011; Nayava et al 2011; Thapa and Joshi, 2010; Pant, 2011; Lama and Devkota, 2009; Bastakoti et al 2011).

Many studies highlightcommonly cited adaptation based on techniques applied for more general crop management, and representative of the early literature on agricultural adaptation. This includes the use of new crop varieties and livestock species (e.g. that are better suited to drier conditions), irrigation, crop diversification, adoption of mixed crop and livestock farming systems, and changing planting dates.Otherstudies also highlight the use of climate information for planning (short-term and seasonal forecasts) and early warning systems, linkage with agricultural extension and agro-meteorological information, agricultural research, and capacity building and awareness-raising. Across the studies a number of agricultural adaptation options commonly emerge which include:

- Capacity building and knowledge, e.g. R&D, awareness raising programmes, meteorological system strengthening.
- Disaster Risk Reduction, e.g. promoting crop insurance programs, strengthening drought and flood early warning systems
- Water supply and irrigation, e.g. developing small-scale irrigation and water harvesting schemes.
- Water related options, e.g.integrated water resources management, hydrological forecasting.
- Improving the natural resource base, e.g. agroforestry or sustainable land management.
- Improved transport and access to roads, e.g. increasing the length of paved roads, improving maintenance, and strengthening critical nodes and bridges.

Much of the recent literature reviewedidentify a range of sustainable agricultural land management (SALM) practices, which for example, adopt techniques to improve soil water infiltration and holding capacity, as well as nutrient supply and soil biodiversity, and include options such as agroforestry, soil and water conservation, reduced or zero tillage, use of cover crops, various soil and water conservation structures, and grazing land management. Many of these overlap with the other recent options advanced on climate smart agriculture (climate compatible agriculture), e.g. conservation agriculture and agroforestry. The latter include options/initiatives to limit the soil-based emissions from agriculture and limit the pressure on forests from the expansion of land under cultivation (e.g. to intensify agriculture through usage of improved inputs and better residue management, create new agricultural land in degraded areas through small-, medium-, and large-scale irrigation, introduce low-emission agricultural techniques, ranging from the use of carbon-and nitrogen-efficient crop cultivars to the promotion of organic fertilizers.

It is often reported that many early agricultural adaptation options, particularly climate smart options, are 'no regrets', i.e. they have positive returns (as a net present value). However, recent work highlights that transaction and policy costs, as well as potential barriers, have not yet been factored into such assessments (i.e. for climate smart agriculture) and increase the costs of these measures considerably(FAO, 2011).

Similarly, the international literature highlights a range of prioritized measures to increase the productivity and resource efficiency of the livestock sector while addressing carbon emission. These are related to increasinganimal value chain efficiency in order to improve productivity. These include higher production per animal and an increased off-take rate, to support consumption of lower-emitting sources of protein such as poultry, to manage land to increase its carbon content and improve the productivity.

An important finding from the international literature – and reported in some studies in Nepal - is on the differing applicability of various technologies to specific risks and locations. Not surprisingly, this finds that adaptation options perform differently according to region and agro-ecological zone. For example,some options (or sets of options) are more applicable for high rainfall areas while others are applicable for low rainfall areas. This provides an important feedback for adaptation planning as the effects of adaptation varies by region and location.

However, while there are a number of studies that list adaptation options, the quantitative analysis of these options are much more limited, with a few limited examples using conventional farm management techniques in crop models (e.g. Rai et al). There is very little cost information specific to Nepal, with only a handful of studies (seeIIED, 2011). A major gap therefore exists on the quantified analysis of a range of short-medium term measures, especially in the context of uncertainty, and their applicability to different agro-ecological zones.

Moreover, adaptation involves more than just technical options. Previous studies highlight that adaptation strategies are affected by informal and formal institutional support, provision of information on future climate change, and current levels of climatic variables. This shows that successful adaptation will require a move beyond a simple set of options, and needs to consider socio-institutional issues and capacity. In practice, adaptation will be governed by a host of factors. It is also highlighted that previous climate shocks have led to existing coping or adaptation strategies, particularly at farm level (i.e. autonomous adaptation) including migration (itself an extreme form of adaptation).

Very similar findings have been foundin the water sector. Many adaptation options (to address floods) are built around traditional disaster risk reduction and management. These are capacity building and awareness raising, enhanced meteorological and hydrological information, early warning systems, protection programmes, insurance, etc.

Similarly, many of the water adaptation measures recommended are extensions of water management, with options including awareness raising, research, more efficient management of existing water supply infrastructures; institutional strengthening; better hydrological forecasting systems and data collection/monitoring (including glacier and glacial lakes); strengthening of (integrated/sustainable) watershed management programs; improved water management technologies (including the link to agriculture) and coordination of water resources development, as well as water conservation and use-efficiency improvements / loss reductions(WECS, 2011; Rees et al, 2004). They also include a range of options for floods and climate induced hazards which in addition to above include enhanced disaster risk management and early warning systems, disaster response planning, forest protection and afforestation/reforestation and terracing to prevent landslides, dike or embankment construction, flood hazard mapping, land-use planning and control, measures to maintain dam effectiveness and many others. As highlighted above, there has also been a greater interest in insurance, including index based insurance for agriculture, micro-insurance, and a greater focus on hazard insurance, at the regional (sub-continent) and national scale.

There is some discussion of adaptation costs for flood protection in NCVST (2009) which reports that autonomous adaptation has a higherbenefit to cost ration than embankment building (based on analysis in the Rohini basin) but that structural measures are cost-effective in densely populated areas. It also reports that flood control has different impacts on different groups, and highlights the issue of shifting vulnerability (e.g. downstream). It reports on studies that advance forest buffers, raising of houses, EWS, and expansion of local coping strategies (e.g. boats) for adaptation to floods. Importantly, it highlights that some adaptation options are path-dependent and irreversible (e.g. embankments) and therefore lock-in decisions (rather than providing more flexible approaches).

As with the agricultural sector there is a more recent focus on broader sustainability objectives including ecosystem services. As an example, the ADB PPCR (2011) is advancing climate resilience in mountain regions through watershed management that aims to reduce erosion and downstream sedimentation, enhancing soil moisture and groundwater recharge, and enhancing surface water conservation and storage, through specific adaptation options such as rehabilitating degraded watershed lands, regenerating forests, implementing conservation farming, protecting water infrastructure from erosion and floods, constructing or improving small-scale water storage facilities and distribution systems, and applying on-farm water conservation.

For hydropower, most studies highlight the need to raise awareness and research (inventories and monitoring of glacial lakes), land-use planning, early warning systems, though some also consider more extreme options such as relocation of population(OECD, 2003). Other studies advance micro-hydro, which serves multiple rural development objectives, and could also help diversify GLOF hazards, for actions to reduce rapid run-off, and others highlight the potential for reducing current electricity losses which are high, as a form of no regret option. A number of technical options also exist to enhance production whilst building resilience, particularly built around retro-fitting to upgrade the efficiency of power generation facilities and offset any potential decrease in river flow.

It is clear that a number of challenges are involved in looking at practical adaptation – and assessing the subsequent priorities quantitatively in Nepal. A number of important issues highlighted for the study include:

- A simple interpretation of the climate model projections can bias the adaptation strategy response. If drier scenarios are considered, then the focus moves to water storage. A move to multi-model projections and uncertainty instead emphasizes a move to more flexible options.
- There will be strong regional differences in the appropriate responses across the country, i.e. between the plains, mid-hills and mountains, and in practice between individual agro-ecological zones (and sub-zones). Different areas will involve a different balance of risks, different projected changes in climate, and different wider drivers (such as existing degradation or water availability and demand), etc. A one-size-fits-all approach is likely to be inappropriate because of these differences.
- There will also be different responses according to whether farm or community based adaptation is considered, or broader public sector planned adaptation, as well as policies to enhance responses in the private sector.
- Many plans for the agricultural sector need to address wider water management, and the cross-sectoral linkages across the economy and to all stakeholders. Similarly, the consideration of water should take into account the multi-functionality of water, and future demand from various sectors, and to integrate flood management within the context of other important priorities. Importantly, there are often differences when studies assessadaptation strategies on a sector-by sector basis, compared to when they consider economy-wide linkages, i.e. the direct plus indirect adaptation costs increase significantly.
- Many of the options discussed above are already being implemented through existing policies and programmes, and particularly the SPCR, which is addressing many early options in the flood hazard, hydro-electricity and agricultural areas. These aspects need to be taken into account in the analysis, as they represent the 'with policies' scenario, i.e. they are already in the baseline and will reduce economic costs.
- Adaptation options will have to address wider social, governance and institutional issues. These include potential barriers such as of scarcity of arable land, poor accessibility to market, rigid traditional practices, high demand for sufficient labour, water and fertilizer. There are important social dimensions for future adaptation, and studies on stakeholder perceptions for adaptation reveal that these are complex. Understanding these social-institutional issues is, however, key for successful adaptation.

# PART 2: PROPOSED IMPLEMENTATION PLAN

The previous section reviewed the existing information. This section of the report outlines the implications of the review findings, and uses these to propose an updated implementation plan for the rest of the study. This also outlines the specific tasks and activities, and identifies the accompanying capacity building and stakeholder engagement plans.

## Proposed Method and Approach

Key Summary Points:

- Assessing the current risks of climate variability, the effects to emerging climate trends, and long-term future climate change involves the analysis of a number of different elements.
- These cannot be addressed with a single analytic method – there is a need to put together building blocks to form the overall evidence base, i.e. using multiple analytic streams.
- The study has therefore proposed a method that starts with current climate variability and extremes, considers the medium-term challenges linking with development, and then considers the future long-term challenges of climate change. When combined, these allow analysis of economic costs – and adaptation responses – that together link to a climate compatible development pathway.

As the review has shown, there is considerable information on the potential impacts of climate change, and many potential adaptation responses, but less on the economic costs. However, many quantitative analysis in Nepal has focused on the medium-long term effects of climate change, considering technical adaptation options. While such studies provide valuable information, it is clear that on their own, they do not meet the objectives of the current study, as they t have insufficient consideration of the immediate and short term policy issues. More importantly, they do not take into account the dynamic nature of the future changes – from short-term trends to future major climate change, and they do not have adequate consideration of the uncertainties in future climate change projections.

Furthermore, most of the existing studies in Nepal – especially related tofuture climate change – do not have enough consideration of wider non-climatic drivers, and they do not take enough account of institutional issues, existing capacity and current policies. The review has shown that the relative importance of climate change must be balanced against other drivers, broader vulnerability, and that adaptation needs to take account of planned development policy. Good development will (mostly) reduce vulnerability to climate change, and adaptation needs to be integrated and mainstreamed within development plans, rather than being presented as a set of stand-alone actions that are implemented anew. Indeed, many existing development actions are the forms of early adaptation, and this baseline of existing measures has to be included when assessing the additional actions needed for climate change. Further,it can often be difficult to differentiate what falls under development and what falls under adaptation.

As a result, we propose a different approach for this study, based around assessing the economic costs over time starting from the present, and viewing**adaptation as a pathway** (Downing, 2012). This has a more complex and dynamic view of climate change, bringing together a number of evidence lines over different time periods to form an overall view of the impacts and economic costs, and then appropriate responses.

The approach is based on a conceptual framing of adaptation as a combination of strategies and actions that span over time, responding to emerging and changing risks, with high uncertainty.

**From Development to Climate Change Adaptation**

The baseline for climate adaptation is **Good Development** that contributes to societal goals of economic and social welfare. While this is not part of a climate adaptation regime per se, mainstreaming integrates climate and development so that the two cannot be separated. A typical strategy related to agriculture and land use is sustainable land management to improve soil fertility and water holding capacity. Such strategies have been common for many decades and have benefits in terms of reduced water stress in seasons of below-normal rainfall.

Supporting climate change is **Adaptive Capacity and Planning**, enhancing the individual and institutional competence for planning climate resilience. Such capacity is closely embedded in the development baseline of good governance and organizational management of environment, social development and economic growth. However, additional effort to address climate change is required; a typical strategy is support to develop a climate change strategy that coordinates climate resilience planning across stakeholders at the national level.

**Reduced current vulnerability,** especially to cope with weather-related disasters and extreme events,is an imperative at present. Better coping in the near term can be expected to have significant benefits in reduced impacts in the future. Hence, this mode of adaptation is a mix between the baseline of development and future climate adaptation. A typical strategy is seasonal climate forecasts tailored to food-insecure regions and vulnerable households with support to implement a range of disaster management measures (both on-farm and diversified economic activities).

**Climate Resilience** is a broad strategy to ensure that the climate risk does not disrupt development pathways, recognizing that future predictions of climate change impacts are highly uncertain. The focus tends to be on short-term actions, but as part of a robust strategy to achieve resilience in light of a range of potential futures. Although this mode has features of reducing current vulnerability, a typical strategy might be enhancing social protection and poverty reduction through improved micro-finance systems that support small scale enterprises so as todeliver improved public services.

The penultimate goal of climate adaptation is **Targeted Climate Change Actions.** This mode has the specific purpose of reducing specific climate change impacts—those effects that are additional to current vulnerability. Since these impacts cannot be accurately predicted or attributed to the additional effects of climate change, this mode is only justified for decisions where there is a high cost of failure if climate change is not considered. For example alteration of major hydrological systems to ensure that there is minimal interruption of services given as a 'worst case' scenario of water availability.

This ranges from good development through to targeted actions to reduce future impacts of climate change. Analytically, the key concepts behind the proposed approach are:

- To start from the position of the present, and look at the issues of current climate variability and climate extremes, including their economic costs. This is crucial to understanding the current adaptation deficit. It also allows the identification of early quick wins (no regret options).
- To consider other drivers of risks, and how these might change over the coming decades. This allows the study to ground the analysis in current policy, and consider non-climate drivers. It also allows the direct analysis of current Government policies, development and sectoral plans, assessing whether these are resilient to current and emerging climate change, or whether the plans need amending to enhance climate resilience. This starts the process of embedding (mainstreaming) climate change into current development.
- To consider downscaled projections of future climate change, taking into account the wide range of scenarios and climate models by considering uncertainty.
- To assess the longer-term effects of future climate change, particularly focusing on areas that might require some early action now, i.e. in relation to infrastructure (long life-times), major impacts and economic costs, etc. This recognises that adaptation actions might be needed in the short-term to allow adaptation to occur effectively in the future.

The advantage of this approach is that it starts with the current situation and looks to the future. By considering sector plans, it aligns to the current development plans of the country, and assesses the risks of climate change to these plans and the actions needed to mainstream resilience.

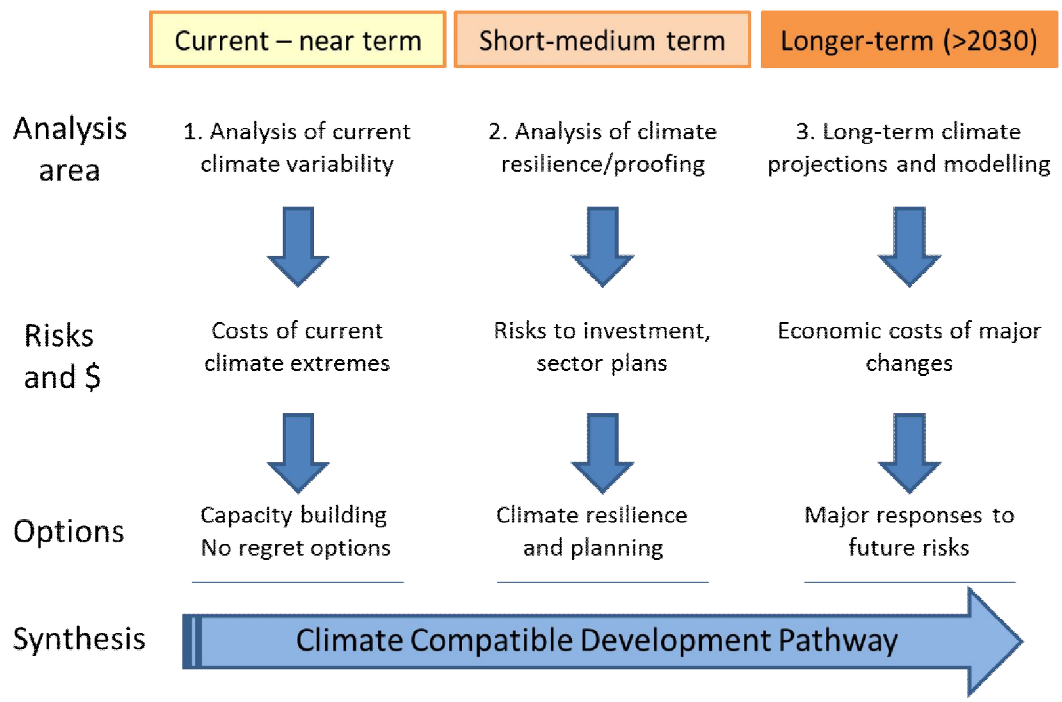
These elements can be combined to provide a view of the economic costs over time, and allow a more direct linkages to adaptation, by allowing the development of an overall climate adaptation strategy or pathway (over time), i.e. a Climate Compatible Development Pathway.The study is therefore dividedinto three time periods.

**1) The costs of current climate variability and extremes in Nepal**. This will provide the analysis of near-term economic costs, including potential impacts from changes in climate variability. For adaptation, the focus will be on addressing short-term climate variability (now and for the next 5 – 10 years) – focused on current and emerging trends, and identifying short-term, "no and low regrets" actions to deal with these.

**2) The risks to current plans over the short-medium term in Nepal**. This will provide an initial risk screening of the potential impacts of climate change on current plans, including the associated economic costs. For adaptation, this will focus on building climate resilience (for the next 5-15 years) – focused pragmatically on incorporating climate change into existing plans, using insights from short-term and long-term climate risks.

**3) The longer term impacts and economic costs of climate change to Nepal**. This will provide an analysis of the more traditional impacts and economic costs (or benefits) of climate change in key sectors, using information from scenario-based impact assessments. For adaptation, the focus will be on planning for medium to long-term climate change (2025 and beyond) –identifying priorities for early action.

Thethree work streams are outlined below:




Source GCAP

**Figure 23. Overview of project methodology**

These work streams are then drawn together, to form an economic analysis to provide headline and sectoral estimates of the impacts and economic costs (or benefits) over time (from the current to the future). This will allow an analysis of an appropriate climate compatible adaptation response. A key benefit of the approach –

and one that is different to other (previous and on-going) studies - is that the cost estimates are captured and presented in a way that is of most use for subsequent adaptation assessment. Importantly the adaptation responses look to form a set of complementary activities, together forming an '**adaptation pathway**' that considers current and emerging risks, takes account of uncertainties, and ensures that the synergies and inter-linkages are accounted for.

Although the primary aim of the study is to focus analysis at the national level, because of the diversity of Nepal's agro-ecological / climatic zones, a national adaptation pathway will need to take this heterogeneity into account This poses a key challenge, i.e. whether the analysis should be national level and top-down, versus sub-national level and bottom-up, and the degree of disaggregation used.

Considering the above issues, our proposed approach is therefore to work at a national level, but todifferentiate between the three major agro-ecological/climatic zones, i.e. between the Terai, Hill and Mountains, to consider what impacts and economic costs arise in each of these zones, and to design appropriate options for different areas of the country.

It is highlighted that there are regional (political) disaggregation issues, alongside the agro-ecological classification. It is not possible to undertake a detailed region by region analysis, and build this bottom-up assessment into an aggregated national plan, but it is recognized that many of the issues with adaptation are institutional, and therefore it is useful to take account of the regions in considering the move towards practical implementation.

The proposed sectoral coverage is on the agricultural sector, including crops, livestock and arable land, and on the water sector, covering irrigation (and the linkage with agriculture), hydropower and water-induced disaster. However, it is also recognized that there are strong cross-sectoral linkages with other sectors, and these will be considered in qualitatively terms.

The three specific work streams, and the synthesis step, are described in detail below. The section also outlines the stakeholder consultation and capacity building activities.

## Workstream 1) Addressing Current Climate Variability and Emerging Trends

This workstream focuses on the costs of current climate variability and extremes in Nepal. It will provide the analysis of near-term economic costs, including potential impacts from changes in climate variability. It will identify immediate short-term actions, focusing on no regret options, associated with addressing short-term climate variability (now and for the next 5 – 10 years) to address current and emerging trends.

The key objectives, methods and outputs are summarized below.

| Objectives | Data, Methods and Models | Outputs |
|---|---|---|
| Assess current and near-term economic costs from climate variability.<br><br><br>Identify and assess immediate short-term actions. | Climate data and trends (by 3 zones)<br>Economic analysis of databases of current extremes.<br>Analysis of agricultural statistics.<br>Stocktake of existing adaptation options using review and consultation. | Headline impacts and economic costs of current variability.<br><br><br>Identified list and initial analysis of options, for different risks and zones. |

The first workstream aims to assess the current and near-term economic costs of climate variability, including emerging trends, and identify immediate short-term adaptation actions, collating and assessing the options that could be advanced in the short-term to address existing risks and emerging trends.

The outputs will form the first part of the economic costs analysis, and also the climate compatible development pathway, focused on the existing climate resilience deficit and likely short-term trends from early climate change. It will draw on the extensive number of studies carried out in Nepal.

In advancing this task, the review above has provided some important insights, notably:

- It is very difficult to work with aggregate metrics (such as GDP) at the national level, and generate clear and unambiguous relationships, not least because of the heterogeneous climate and agro-ecological zones across the country. Some sub-national disaggregation will be needed.
- The data on climate trends shows that outside of rising temperature, there are complex trends on the direction of short-term changes, i.e. in terms of average, variability or extremes. This uncertainty needs to be factored into short-term responses.
- The available information on the frequency and intensity of flood and drought events does not appear comprehensive. Although on-going work is addressing such issues, there does not seem to be good data on the (full) economic costs of these events or the effects of variability.
- Different risks and economic costs arise in different areas (and agro-ecological zones) – and thus adaptation measures should reflectsuch differentiated responses.

The practical activities in the task are:

1. Taking the three main agro-ecological and climatic zones and compiling historical climate data (including variability) and information on emerging trends (noting that information from a larger number of climatic zones, east to west, will also be compiled).

2. Systematically assessing the risks, and impacts and economic costs in each area. For agriculture, this will look at available agricultural statistics and information. For extreme events, the analysis will take the various databases of events, compile them, and undertake economic analysis to draw out the potential economic costs and benefits (losses and gains).

3. Collating a list of adaptation options relevant for these risks, based on the literature review. Furthermore, to complement this with a stock-taking and ex post analysis, compiling where various options have been applied in Nepal, building up the evidence of applications split by agro-ecological zones, collating information on costs, etc. In terms of the adaptation options, a major focus will be:

- Coping strategies, building on existing studies.
- Capacity building, as a key precursor step to successful adaptation, providing the necessary architecture to enable future decision making.
- Short-term options for resilience.
- No regret options such as productivity enhancing techniques that offer resilience and economic benefits, including options already identified in national plans and other studies.

The outputs will be headline estimates of the impacts and economic costs of current climate risk, and an assessment of potential short-term options.

The work stream will involve a strong element of consultation with Government, donors, local technical intuitions, and other stakeholders including experts.

## Workstream 2) Building Resilience: Addressing Risks for Development

This workstream focuses on the risks to current plans over the short-medium term in Nepal. It will provide an initial risk screening of the potential impacts of climate change on current plans including associated economic costs. For adaptation, the task will focus on building climate resilience (for the next 5-15 years) – focused pragmatically on incorporating climate change into existing plans, using insights from short-term and long-term climate risks.

The key objectives, methods and outputs are summarized below.

| Objectives | Data, Methods and Models | Outputs |
|---|---|---|
| Identify risks (and potential economic costs) of climate change to current plans, and potential scale of effects.<br><br>Identify options to enhance resilience of plans. | Stock-take and review of major development and sector plans, UNDP Investment and Financial Flow Analysis (IFF), Analysis National Planning Commission climate-resilient planning, and other climate screening. | Assessment of climate resilience of current major plans.<br><br>Additional activities for climate proofing current plans. |

The second workstream aims to assess the risks to existing development plans, and looks to build resilience consideringemerging risks. It concentrates on national level policy and looks over the next 5 – 15 years, consistent with planned development in Nepal. It has a strong focus on risk screening of the current development plans and sector programs, looking at whether current plans are resilient, and where further strengthening is needed, including the cost implications. This draws on the existing risks from the first workstream, but also considers emerging climate change signals. The focus is on the short-medium term. The review above has provided some important insights, notably:

- National development plans anticipate very large changes in the country, which will dramatically affect the sectors here (e.g. in relation to proposed changes to agriculture). It is important to examine how these plans will change future risks and vulnerability, as well as assessing if the plans are at risk.
- There are a number of existing Government plans and policies, some of which are already moving to include climate resilience. A notable exampleis the National Planning Commission (NPC) climate resilient planning and screening methods.

The practical activities in the task are:

1. Identifying a list of key existing national development policies, plus major sectoral policies and planned programmes in the agriculture and water sectors.

2. Building up a baseline analysis of each of these policies, e.g. looking at the planned investment (using an investment and financial flow assessment framework) to establish baseline flows.

3. Assessing the risks to these plans, including the potential economic costs, drawing on the material from workstream 1 and the climate model projections from workstream 3, and examining if they have already included climate resilient options.

4. Assessing the potential adaptation responses that would enhance resilience to these risks, drawing on the information from stock-take of adaptation options from workstream 1 and supplementary analysis. This will be used to provide recommendations on how to make these plans more resilient.

The outputs will be an analysis of current risks, and potential costs of climate change to these plans, and guidance on how existing policies might need to be strengthened to make them more resilient.

## Workstream 3) Preparing for Medium to Long-term Impacts and Costs

This workstream focuses on longer term impacts and economic costs of climate change to Nepal. It will provide an analysis of the more traditional impacts and economic costs (or benefits) of climate change in key sectors, using information from scenario-based impact assessments. For adaptation, the focus will be on planning for medium to long-term climate change (2025 and beyond) – identifying priorities for early action.

The key objectives, methods and outputs are summarized below.

| Objectives | Data, Methods and Models | Outputs |
|---|---|---|
| Assess medium-longer term issues.<br><br>Assess adaptation options for early action to address these potential risks. | Downscaled climate change projections.<br>Interpretation of existing impact models (e.g. crop model results).<br>New Impact Assessment analysis (agricultural and water sector modelling).<br>Investigation of Computable General Equilibrium and Input-Output modelling.<br>Scenario analysis.<br>Identification of options and future pathways. | Identification of key risks and potential economic costs in the medium-long term of Nepal.<br><br>Identification of short-term actions to address longer-term risk. |

The aim of this work stream is to assess the medium-longer term impacts and economic costs from climate change, and longer term strategic issues, then to work back and assess what the priorities are for early (adaptation) action to address these risks. This includes a more traditional longer-term analysis of climate change, considering future climate model projections, and potential impacts.

However, it is stressed thatwhile this study proposed to use the same approach and models as a classic impact assessment, which undertakes detailed modeling studies of the impacts and potential economic costs (and traditional optimized analysis of the costs of adaptation to specific future projections), the proposal differs from a standard I-A assessment in one critical way: it will consider a much wider range of uncertainty from the use of different RCMs and alternative impact assessments, complementing modeling work with interpretation. This will build up a range of possible future outcomes and economic costs. It will then identify the key issues in the long-term that might require early adaptation, i.e. to identify the long-term issues that need to be built into a climate resilience plan today. This involves consideration of options that will allow learning, precursor activities to enable later actions, and ensuring early actions involve flexibility and do not prevent important longer-term adaptation (i.e. cutting off options).

The review has provided some important insights for this task:

- There is very high uncertainty in the future projected climate change from the climate models, across the range of scenarios and models, even for downscaled model outputs. A focus should be on capturing this uncertainty and considering the implications for the longer-term, rather than trying to predict central trends or outcomes and then optimise long-term strategies.
- There remains important additional uncertainty when progressing to impact assessment, e.g. in terms of effects on crop yields or hydrological flows. It is important to recognise this additional uncertainty, i.e. not just in relation to climate model uncertainty.
- There is already a large impact assessment (and economic cost) study being undertaken for Nepal as part of the ADB project. The study needs to avoid duplication with this study and linkages between the two studies will be explored.
- For adaptation, the results of the impact modelling work (e.g. crop models, or detailed water management models) need to be combined with wider interpretation of key risks to maximize information for practical adaptation, i.e. examining plausible changes and uncertainty across a wide range of

information, identifying thresholds or switching points where different policies might be relevant. This will ensure a focus on robustness and resilience, rather than thinking about adaptation as an optimization to a central projection.

- There are strong cross-sectoral linkages in the risks of climate change to the agricultural and water sectors (notably in relation to demand) and it will beusefulto align the analysis across these two sectors.

The practical activities in the tasks are:

1. Collate the climate model projections for Nepal, drawing together the existing climate model projections for the key agro-ecological and climatic zones. This will focus on downscaled data, using the statistically downscaled projections and available regional climate model projections including from the DHM climate portal and the 2nd National Communication.

2. Synthesize the existing information on future impacts and economic costs, i.e. collating together the crop model and ricardian analysis, and building up envelopes of possible changes across the climate model projections and impact assessment information (e.g. crop production losses, potential shifts in agro-ecological zones, etc.). Similarly, to synthesize information on future hydrological changes, flood risks, etc.

3. Undertakenew impact assessment (modeling) work, with new modeling in the agricultural and water sectors. This work will extend existing work undertaken in Nepal. It will also build links with other similar activities being undertaken in the Second National Communication and the ADB RECCSA study and the study will also investigate the potential for covering additional areas (e.g. risks such as to livestock) not covered by existing work, and to provide complementary information that could be extremely useful (e.g. changes in agro-ecological zones as well as crop productivity to consider long-term land-use issues). The modeling anaylsis will include agricultural modeling using the DSSAT model, and analysis on hydro-power using a hydrological modeling system linked to hydro-power models (TANK/HEC HMS and Valoragua/WASP).

4. Assess the potential wider economic, indirect and macro-economic costs of the impacts of climate change.

5. Draw together a set of scenarios of key long-term issues. Identify how these long-term issues could evolve, including issues of major thresholds or switching/tipping points, and identify key risks and the decisions evidence). As examples, this is likely to focus on:

- Major changes in agro-ecological zones that affect the viability of current critical crops, or major export crops, that would require pro-active planned adaptation.
- Cross-sectoral limitations for water, that involve competing demands across agriculture, energy and household/industrial demand (e.g. and that might involve major storage projects).

The task will then work back and identify where early actions are needed, particularly over the next five years to ensure early resilience measures are progressed and options are kept open. This will include analysis of what needs to be measured and monitored to provide information to track these changes and respond appropriately, or where early action is needed to prevent long-term impacts, or keep future options open. As examples, it will involve

- Decisions that are irreversible (such as land-use change) and how to respond to agro-ecological shifts that that go beyond farm level adaptive responses (i.e. that require some level of planned national thinking).
- Decisions that take a long time, and thus need to be planned for in advance, such as major water projects.
- Decisions on infrastructure, which due to long life-times, may require consideration of longer-term change (and incorporate this in short-term design).

This is likely to involve a mix of low cost options such as monitoring and measurement, but also more expensive options which involve opportunity costs in the short-term. A key focus will be to identify areas of potential future lock-in and loss of future options.

The outputs will be headline estimates of the impacts and economic costs of long-term climate risks, identification of key risks, and an assessment of early actions needed to start planning for – and monitoring – these risks.

## Bringing it Together: A Climate Compatible Development Pathway

This task will bring the previous information together, assessing the evolution of potential costs of climate change over time, and building up a climate compatible development pathway to address these.

The key objectives, methods and outputs are summarized below.

| Objectives | Data, Methods and Models | Outputs |
|---|---|---|
| Assessment of evolution of economic costs over time.<br><br>Compilation of adaptation options and pathway. | Expert analysis and workshops. | Economic impacts of climate change on key sectors.<br><br>Climate compatible development pathway, outlining steps in addressing risks over time. |

The aim of this work stream is to synthesize the results from the three work streams above, and compile the cost estimates and response options – taking into account the inter-linkages.

It will compile the information from the three work streams to provide headline and sectoral estimates of the impacts and economic costs over time (from the current to the future), and then , consider the potential options to address these identified risks, identifying the complementary activities over time, which together form an '**adaptation** or **climate compatible development pathway**'.

The pathway will use a very simple categorization which lends itself to the temporal dimension above, i.e. considering options in terms of:

- Capacity building.
- Short-term measures, which may include benefits in addressing current climate variability, and is likely to include the types of options classified as 'no regrets', 'win-win' or 'low cost'.
- Medium-long term measures, which may need early action due to the long-term nature of the exposure of investment (lifetime of infrastructure), the length of the decision process, or the need for planning to keep later options open (particularly for major or irreversible effects in the long-term).

The practical steps in this task will be to:

1. Draw the information together to provide pathways of emerging risks and economic costs for the key sector over time. The first step is to derive the economic costs of the above mentioned climate impact assessments on key sectors. Total cost implications (for the various climate change scenarios) for crop production, arable land, livestock, and irrigation, hydropower and water-induced disasters) will be produced.

2. Bring together individual options from each time period and compile these together against these risks, looking at inter-linkages and synergies, and taking account of any information on the potential costs, benefits and wider attributes of the options.

This output will be a series of climate compatible pathways, which reflect the mix of different sectors, risks and national vs. regional issues.

## Consultation, Communication and Capacity Building

A key theme of the project is to ensure the effective **stakeholder consultation** on the approach, and communication of the findings.

| Objectives | Methods | Outputs |
|---|---|---|
| Hold consultation meetings with Government and other relevant stakeholders/actors.<br>Agree overall project governance. | Steering Committee meetings.<br>Thematic Working Groups.<br>Consultation, in-country visit and review of existing studies. | Formation of the National team<br>National team / stakeholder workshops. |

The stakeholder engagement focuses on working directly with key Government and wider stakeholders to address the key challenges and issues.Two key stakeholder processes have been set up.

- **A Steering Committee**- In order to ensure full Government ownership and that the outputs will be relevant and useful to Government policy-makers, the project will report to a high-level Government Steering Committee. The Steering Committee will provide guidance and leadership to the study team on project scope and direction, throughout the process, helping the team to identify sub-sectors that are of highest priority.
- **Thematic Groups**- in addition to the SC, an additional level of consultation will be advanced through technical thematic groups. The team has established two thematic groups, representing individuals related to the key sectors of this study, i) Agriculture and ii) Water/energy.Through a participatory consultation process, these thematic groups will help provide input on selection of sub-sectors, provide relevant data and information to the study team, provide technical comments and inputs on the reports, and ensure a common ownership of the project. A key aim will be to bring experts and organisations that are conducting related research, to explore ways of building synergies.

The study team have also developed a **communication plan**. This has:

- Identified overall engagement objectives and levels;
- For each level of engagement, defined, prioritised and understood the target audience and key stakeholders;
- Developed effective engagement pathways and modes of engagement at each level.

As this is a national study which will develop a climate compatible cost effective policy framework, as well as an effective institutional framework capable of implementing the policies and policy guided programs, the communication and dissemination strategy will focus firstly on national policy makers. The second, but equally important, targeted audiences are the local institutions and communities who have to participate in the planning, implementation and monitoring and evaluation of the climate compatible programs at local level, and who must know why the change in policies are urgent for climate change adaptation and mitigation. A third group of stakeholders include development partners, who also need to be informed about the national strategic policies and road maps so that they can develop their country assistance programmes in line with the requirements/need of the country. UN agencies and other regional and international forums/funds will also be within the communication channel.

Finally, a key focus of this project is **capacity building**. Indeed, the transfer of skills and knowledge runs throughout the project. The study is a collaborative in nature(joint venture) with IDS Nepal taking the lead role in Nepal, but involving other partners, and many other stakeholders. The sharing of knowledge is one of the main aims of the project: between experts and practitioners, between experts with state-of-the-art methodologies and those with real-world data sets and applications.

| Objectives | Methods | Outputs |
|---|---|---|
| Development of a capacity building program for Government and local partners.<br>Production of material to ensure local capacity and leave legacy.<br>Hands-on training and online resources. | Expert workshops and study tours.<br>Participatory stakeholder workshops.<br>Day-to-day, on-the-job knowledge transfer and capability building | Expert Workshops .<br>Training event on the study (September).<br>Online training resources / knowledge base.<br>Plan for further capacity building. |

A strong aim of the work is therefore to build capacity in-country, for which the inception phase has developed a capacity building plan.

The plan involves a range of activities, including:

- Ensuring that the tasks are undertaken collaboratively by local and international teams.
- Building-in training and hands on transfer of methods, models, results, with local partners and with Government during the project.
- Bringing in selected international lead experts to provide specialist advice on specific issues and to support the national team.
- Holding specific training workshops, to go through the approaches and methods.
- Providing wider access to climate change impacts and adaptation training.
- Facilitating on-the-job training for national team members (from government, or third parties).

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