Government of Nepal
Ministry of Science, Technology and Environment

Economic Impact Assessment of Climate Change in Key Sectors in Nepal

Study Inception Report
(Abridged Version)

January 2013

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Integrated Development Society Nepal
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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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Foreword

Recent assessment reports, with some degree of uncertainty, are revealing the facts that climate change has already caused loss and damages to the global society and economy and has posed serious risks to the future prosperity of human beings. They further maintain that it has disproportionate impact on different economies and societies based on the geographic location, structure of the economy, level of development, and role of natural resources to the economic development of the country. With a low level of development and natural resource based livelihood, Nepalese economy is highly climate sensitive. As such, Government of Nepal has placed high priority on climate change agenda and has been intensively engaged in establishing legal and institutional arrangements. In this context, Government brought about Climate Change Policy in 2011, instituted climate change Council, established Climate Change Management Division, and initiated Climate Change Budget Code. Nepal has also brought forward mountain initiative and prepared and started implementation of NAPA/LAPA.

Amongst many initiatives recently undertaken, the economic impact assessment of climate change in water and agriculture sectors of Nepal is the important and the most recent one. The importance of such assessment was felt even during the time of the formulation of Climate Change Policy 2011. Consequently, the Policy set a target of "assessment of losses and benefits from climate change in various geographical areas and development sectors by 2013". This project was designed to directly address the target.

This publication is an abridged version of the inception report which first includes a review of the past efforts and initiatives made in this area in Nepal and abroad, and then presents an approach and methodological tools how economic impact assessment of

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climate change will be carried out in water (hydropower and water induced disaster) and agriculture sector. The experts have done a series of consultations/interactions both formal and informal to come up with a feasible approach of impact assessment. Many limitations and constraints do exists while doing such multi dimensional exercises in developing countries like Nepal where data/information are either lacking or inconsistent or inadequate or are not available in disaggregation. It is good that the study team finally came up with a set of approaches and methodology for economic impact assessment, which was peer reviewed by national as well as international experts.

This exercise is a first of its kind and we hope that it will create certain foundation for further analysis. On behalf of Ministry of Science, Technology and Environment, I appreciate the works of the team of experts involved in this project and thank CDKN and all the consortium partners – IDS-Nepal (the lead), Practical Action Consulting, and Global Climate Adaptation Partnership for the support.

19 January 2013

Keshab Prasad Bhattarai
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Government of Nepal, Ministry of Science, Technology and Environment (MoSTE) has been implementing the project "Economic Impact Assessment of Climate Change in Key Sectors in Nepal" through a consortium of international and national organisations with support from Climate Development and Knowledge Network (CDKN). The project has completed its inception phase and has produced an Inception Report containing review of the past work and the implementation approaches of the project. The report was peer reviewed by one national and one international reviewer, and was adopted by the Project Steering Committee representing National Planning Commission, Ministry of Finance, concerned thematic ministries/departments and independent experts.

This publication is an abridged version of the Inception Report. The aim of this publication is to disseminate the review outcome and share the approaches and methods of economic impact assessment of agriculture and water sectors of Nepal.

I acknowledge the significant efforts made by the team of experts who contributed to the Inception Report, and the consortium partners who organised the publication of this version of the Inception Report for the interest of a larger audience.

19 January 2013

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Introduction

At the request of the Government of Nepal, the Climate and Development Knowledge Network (CDKN) is funding a study on the *'Economic Impact Assessment of Climate Change in Key Sectors in Nepal'*. 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 was initiated 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, Nepal, and the Global Climate Adaptation Partnership (GCAP) in the UK. The study has two main objectives:

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

The project aims to be comprehensive, participatory, and of indigenously orientation. 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: inception phase and implementation phase. This snapshot report summarizes the findings of the inception phase. It has two parts – review of current knowledge and Implementation plan.

PART 1: REVIEW OF CURRENT KNOWLEDGE

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 its temporal and spatial distribution, 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

Nepal's economy is largely based on agriculture. It accounts for around one third of GDP, 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 livelihood for around three quarters of the population. The majority (over 50%) of farmers are small holders cultivating less than 0.5 ha (CBS, 2011). 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. These differences are critical in understanding current and future risks, and designing appropriate adaptation responses.

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 only 69.5% of total irrigable area is irrigated (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 studies in 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 done 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, and around 78% of the average flow is in the four major basins, i.e. Koshi, Gandaki, Karnali, and Mahakali. 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 could be used to meet the 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 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

This study builds on the foundation of existing climate studies and plans in Nepal. It includes the Climate change policy (2010), 1st National Communication (GoN, 2004), the National Adaptation Programmes of Action (NAPA, GoN, 2010), the Programme of Local Adaptation Programmes of Action (LAPA 2011), Pilot Project on Climate Resilience (PPCR), the Strategic Program for Climate Resilience (SPCR), and others. Furthermore, climate related initiatives are included in underlying policies on climate resilient planning, disaster risk management, and poverty environment initiatives which are being mainstreamed into sectoral policies, many of which are implementing early adaptation options. Finally, there are also a large number of Government, donor and NGO activities – in place and emerging – that are helping to address existing variability, building resilience and envisioning adaptation to climate change.

Current Climate Vulnerability in Nepal

Key Summary Points:

- Nepal has an extremely varied climate reflecting the 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 from considerable impacts and economic costs from climate variability and extreme events and lacks existing adaptation plans.

Current Climate

Nepal is an extremely complex and varied country climatically. 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 as shown below. The highest temperatures occur during the pre-monsoon period. The lowland regions of Nepal have a warm and humid sub-tropical climate, while the high mountainous regions are cold, remaining well below zero in the winter (PAC, 2009).

The mean annual rainfall in Nepal varies dramatically by region, and perhaps more importantly, by season. The terrain and topography – notably the large mountain systems – have a major influence 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; PAC, 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; PAC, 2009).

Emerging Climate Trends

Looking towards early adaptation, a crucial question is whether the effects of climate change are occurring already, and how these might evolve over the next ten to fifteen years. This study has reviewed the recent trends looking at observational data including recent trend reviews by McSweeney et al., Baidya et al., 2007; Saraju et al., 2008; PAC, 2009; and GoN, 2010).

Asia has shown a consistent warming trend over the last century. The NAPA (GON, 2010) also reported a trend of observed warming for 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.

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., undated) reported a trend of decreasing annual precipitation. However there are number of regional precipitation trends and the NAPA reports that annual 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 showing increased and others show decreased rainfall. 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.

The analysis has been made difficult because of the 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 be analysed in 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 sensitive activities, particularly agriculture. The economy of the country, and the livelihoods of the people,

is therefore very dependent on the climate. 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 & Shrestha, 2008; GoN & WFP, 2011). This 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 droughts 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) yields by 15% and 17% respectively, leading to an annual cereal deficit of 133,000 mt despite a excellent summer crop harvests. Indeed, recent years have seen severe winter droughts. There was one in 2006 combined with extensive summer flooding, and another one in 2009/2010, which is reported to have led to an 11% loss of rice yield, 7% loss in wheat and maize yields leading to a total grain deficit of 400,000 mt (Poudel, 2011).

However, there is 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 & 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 for rice, or winter rainfall for wheat, though some of the 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 be beneficial for early winter crops (such as wheat) as it reduces harvesting losses (Thapa & Joshi, 2010).

Climate variability also affects hydroelectricity production. Hydroelectric plants are dependent on predictable run-off 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). Incidentally, there was a 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 one of the major climate related hazards in the country (GoN, 2010), though landslides, drought and fire are also recorded. 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, and the most severe extreme droughts in Nepal have occurred during winter (see agricultural discussion above).

Some studies have already started building 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[1]. It also looked at the consequences of these events on an average Nepali household using past studies, field observations and bottom-up consultations.

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

[1] The 1998 Rohini River and other Terai 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).

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 the fact that any projection remains 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 uncertain.
- Adaptation policies need to plan for this uncertainty, rather than using this as a reason for inaction.

Some models project a likely increase in annual precipitation over the country, though considerable caution is needed in interpreting the findings. 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) reports a similar variation across scenarios and model projections indicating changes between -30% and +100%.

This is a critical finding for the study. There is 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

This 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 metereological stations (Fig. 1).

TEMPERATURE. All the climate projections show increasing temperature (average and extremes), though the level of increase varies slightly across the models. The Fig. 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 for Kathmandu, 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).

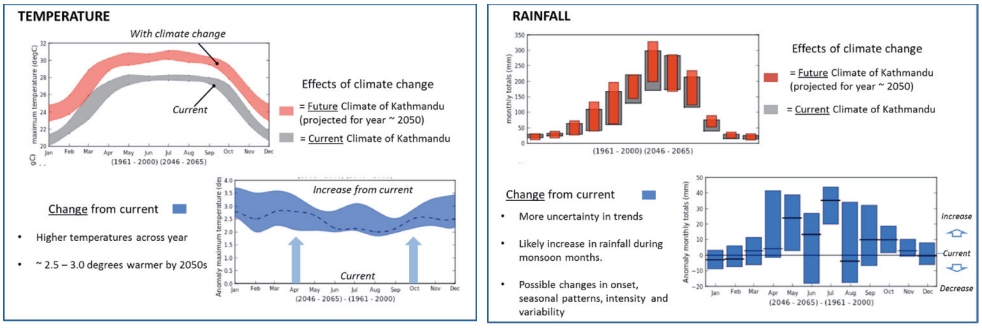

Fig.1: Temperature and Precipitation Projections for Kathmandu (A2, 2050)
Source of data: Climate Systems Analysis Group (CSAG), University of Cape Town, UCT (2012)

Fig. 2 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.

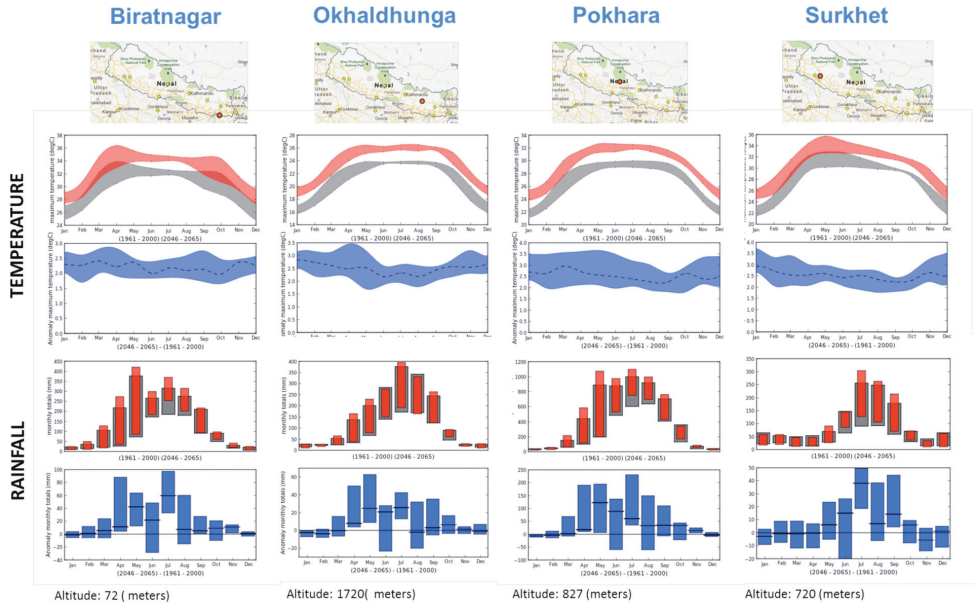

Fig. 2: Monthly daily maximum temperature and monthly rainfall for the mid-century projections (A2) for different sites in the country.

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

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 development into account.
- There is also a need to build resilience to climate change into development policies.

While 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.

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 indicate an 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 (76%) 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 HABITAT, 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) and will remain so in the future.

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 the trade 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 becoming a 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 decsade, and over 10% 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 hydropower 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 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. It is to be noted that 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 in Nepal

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 includes 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 reports that have assessed the future impacts of climate change in Nepal. Many of these are focused in the agricultural and water sectors, and are thus of high relevance to the current study. This study has reviewed these available studies.

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 literatures that have applied crop models (agronomic models) to assess the soil-plant-atmosphere components relevant for plant growth and yield, and also look at the effects of future climate change on crop productivity (GON,

2004; Sherchand et al., 2007; Rai et al., n.d). These studies have found mixed 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 modelling 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 been strongly 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 due to temperature, but also due to future precipitation and water availability. The DHM/APN (Sherchand et al., 2007) study also applied DSSAT. Rai et al. (n.d.), using the DSSAT model, looked at rice in Nepal and reported that modest temperature increases (minimum temperature) have positive effects, but above 2°C change in temperature, negative impacts will start to arise.

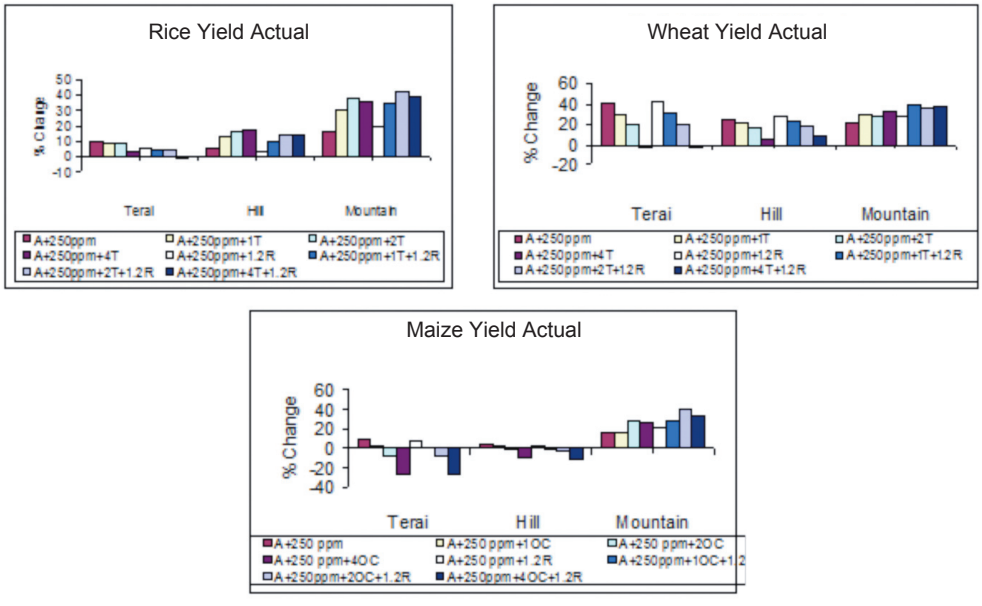

Fig. 3: Rice, wheat and maize yield at different altitude regimes as influenced by climatic variability.

Source: Sherchand et al., 2007

There have also been some Ricardian modelling 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.

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 potential 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.

There is relatively less information available on the potential effects of climate change on livestock. The studies and reviews available (Pokhrel & Pandey, 2011; Sherpa, et al., 2009) indicate 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 sector 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 snowfall and melt, glacier coverage, evapo-transpiration, etc. as well as changes in demand of water. 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 increase and its effects on glaciers/ de-glaciation (Chaulagain, 2006) indicate that climate change could increase

river flows in the short-term by speeding 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 highlighted 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 of water. Rees et al. (2004) report that precipitation will have a major influence on how the deglaciation impacts vary regionally.

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 the lower 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 of 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 that the variability in the mountain context makes such assessments very uncertain.

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

Overall, the studies in 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 a short-medium term effects, most relevant for initial resilience planning. The review also highlights that there is considerable uncertainty, given the underlying information on the climate model projections and its 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 adaptation options for 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 in the Mountains.
- The consideration of uncertainty is critical: there is a need to develop options within a framework of decision-making under uncertainty as a part of an iterative process.

Many studies have highlighted possible adaptation options for Nepal. National processes, such as the NAPA and other studies, have recommended these. The NAPA (GoN, 2010) identified a number of adaptation measures. An initial long-list was prioritized to produce a list of 9 options with an estimated budget of $350million.

Many studies highlight commonly cited adaptation based on techniques applied for more general crop management, and representative of the early literature on agricultural adaptation. Across these 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.

Very similar findings have been found in 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). 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.

For hydropower, most studies highlight the need to raise awareness and research (inventories and monitoring of glacial lakes), land-use planning, and 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. Yet 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 assess adaptation 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, and the 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: IMPLEMENTATION PLAN

The previous section reviewed the existing information. This section of the report outlines the implications of the review findings, and uses them to propose an updated implementation plan. It 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 of 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.

Analytically, the key concepts behind the proposed approach are:

- To start from the present position and look at the issues of current climate variability and climate extremes including their economic costs. This is crucial to understand 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 linkage 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 divided into 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.

The three work streams are outlined below:

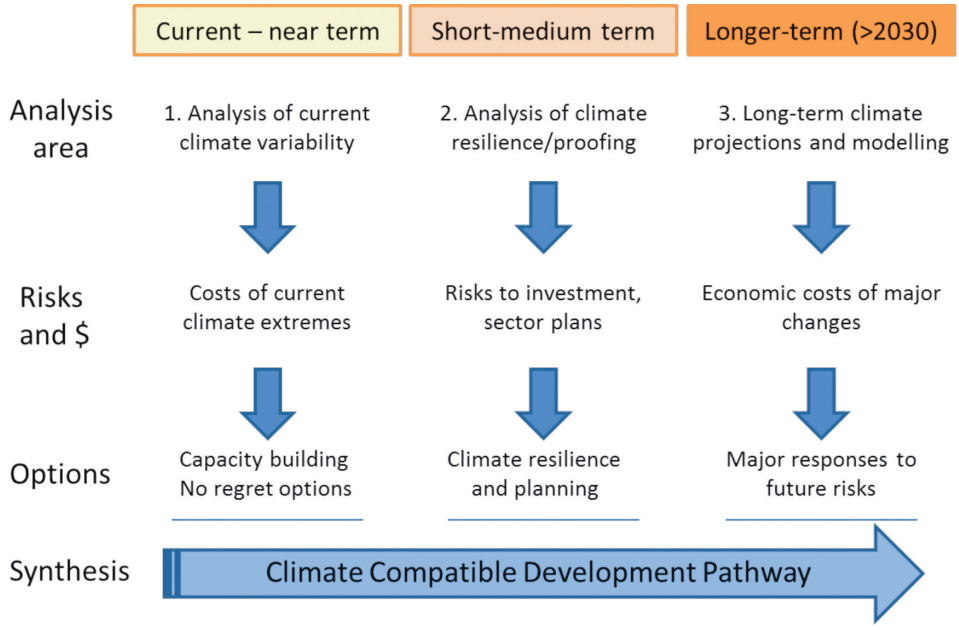

Fig. 4: Overview of project methodology

Source: GCAP

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

Work stream 1) Addressing Current Climate Variability and Emerging Trends

This work stream 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. Identify and assess immediate short-term actions.	Climate data and trends (by 3 zones) Economic analysis of databases of current extremes. Analysis of agricultural statistics. Stocktake of existing adaptation options using review and consultation.	Headline impacts and economic costs of current variability. Identified list and initial analysis of options, for different risks and zones.

The first work stream 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.

Work stream 2) Building Resilience: Addressing Risks for Development

This work stream 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. 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. Additional activities for climate proofing current plans.

The second work stream aims to assess the risks to existing development plans, and looks to build resilience considering emerging 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 work stream, but also considers emerging climate change signals. The focus is on the short-medium term.

Work stream 3) Preparing for Medium to Long-term Impacts and Costs

This work stream 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 (2030 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. Assess adaptation options for early action to address these potential risks.	Downscaled climate change projections. Interpretation of existing impact models (e.g. crop model results). New Impact Assessment analysis (agricultural and water sector modelling). Investigation of Computable General Equilibrium and Input-Output modelling. Scenario analysis. Identification of options and future pathways.	Identification of key risks and potential economic costs in the medium-long term of Nepal. 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 that while this study proposed to use the same approach and models as a classic impact assessment, which undertakes detailed modelling 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 modelling 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).

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. Compilation of adaptation options and pathway.	Expert analysis and workshops.	Economic impacts of climate change on key sectors. 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).

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. Agree overall project governance.	Steering Committee meetings. Thematic Working Groups. Consultation, in-country visit and review of existing studies.	Formation of the National team 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 has 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; and
- 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. Production of material to ensure local capacity and leave legacy. Hands-on training and online resources.	Expert workshops and study tours. Participatory stakeholder workshops. Day-to-day, on-the-job knowledge transfer and capability building	Expert Workshops. Training event on the study (September). Online training resources / knowledge base. Plan for further capacity building.

A strong aim of the work is therefore to build in-country capacity, 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 the 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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