SUMMARY REPORT

Economic Impact Assessment of Climate Change in Key Sectors in Nepal

Government of Nepal
Ministry of Science, Technology and Environment (MoSTE)
April 2014

Integrated Development Society Nepal
IDS-Nepal

Global Climate Adaptation Partnership

PRACTICAL ACTION Consulting

Project Study Team

This project was led by the Integrated Development Society Nepal (IDS-Nepal), working with Practical Action Consulting (PAC) in Nepal and the Global Climate Adaptation Partnership (GCAP) in the UK.

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The project 'Economic Impact Assessment of Climate Change in Key Sectors in Nepal' was undertaken at the request of the Government of Nepal. The project received guidance throughout from the Project Steering Committee. It originated to address the target included in the Climate Change Policy 2011: the assessment of losses and benefits from climate change in various geographical areas and development sectors by 2013. The project and final technical report underwent an international peer review. The views expressed in the report are entirely those of the study team and do not necessarily reflect the views of the Government of Nepal.

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Government of Nepal

Ministry of Science, Technology and Environment

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Foreword

The Fifth Assessment Report of Intergovernmental Panel on Climate Change has shown that climate change is real and its impacts are serious. Due to its low level of development and dependence of its people on natural resources for their livelihoods, Nepal is extremely sensitive to the adverse impacts of climate change. In this context, the Government of Nepal has given high priority to climate agenda, with the formulation of Climate Change Policy, National Adaptation Programmes of Action, National Framework on Local Adaptation Plans of Action, and appropriate institutional arrangements and programmes. One important initiative in this regard is the study project on "Economic Impact Assessment of Climate Change in Key Sectors in Nepal". This project was designed to directly address one of the targets set by the Climate Change Policy.

This publication is the summary of the main report and includes the key findings of the study which was conducted by a consortium consisting of Integrated Development Society Nepal, Practical Action Consulting Limited, Nepal and Global Climate Adaptation Partnership, UK, over the period of two years. Such a multidimensional study by its very nature, has limitations specially in a country like Nepal where data are either lacking or inadequate or are not available in disaggregated form. Despite this and the uncertainty inherent in future projection of climate impacts, the study team has come up with a useful report that highlights the impacts and the deficit in adaptation to climate change impacts. We hope this report will serve as a valuable addition to the knowledge base on impacts of climate change and will contribute to policy making and programme formulation.

This study is the first of its kind and we hope it will create a basis for future studies covering other sectors of the economy. The methodology followed could also be useful for conducting similar studies in other parts of the world.

On behalf of Ministry of Science, Technology and Environment (MoSTE), I thank the efforts of the team of experts involved in the study and members of the Steering Committee for guiding the study. I also appreciate the funding support of Climate and Development Knowledge Network.

The views expressed in this summary report and the main report are those of the study team and are not necessarily those of MoSTE, Government of Nepal.

Dr. Som Lal Subedi
Secretary

Key Findings

This study provides estimates of the impacts and economic costs of climate change for key risks in Nepal. The key findings are summarised below.

Nepal suffers high economic costs due to current climate variability and extremes

- The economy of Nepal and the livelihoods of its people are very dependent on the climate: a large proportion of the country's Gross Domestic Product (GDP) is associated with climate-sensitive activities.
- Current climate variability and extreme events lead to major impacts and economic costs in Nepal.
- These are dominated by floods, but also include rainfall variability on agriculture (rain-fed agriculture, soil erosion, droughts) and low season river flows reducing hydroelectricity generation.
- The estimated direct cost of these events is equivalent to 1.5–2% of current GDP/year (approximately US$270–360 million/year in 2013 prices), and is much higher in extreme years, rising to 5% or more. This is high by international levels.
- Consideration of the additional indirect and macro-economic costs of these impacts could increase current estimates by 25–100%.
- The analysis above was complemented with a series of local case studies, which included new field surveys.
- These studies found that the recent changes in the climate are already leading to impacts on local communities. These are magnifying existing inequalities among groups in society, with distributional differences by area and by gender.
- Nepal is therefore not adequately adapted to the current climate – the country has a large existing adaptation deficit which is a priority for early action.

Future climate change is likely to increase current impacts and lead to additional future costs

- Climate change will exacerbate the impacts above, as well as introducing new risks; though in some sectors/regions it could also lead to benefits.
- The study assessed the potential future impacts in Nepal using climate and impact models. This was challenging due to the complex climate and hydrology, the very large changes in elevation across the country and the influence of the regional climate.
- The study used existing climate model projections of future climate change. This focused on downscaled outputs for Nepal, which have the high spatial resolution needed to capture the elevation gradient from the low plains to the high mountains.
- The study used downscaled regional climate model simulation projections for Nepal, focusing on a medium-high emission scenario (the SRES A1B scenario) but with interpretation of uncertainty from other model runs (including the DHM portal and statistically downscaled climate model results).
- These downscaled projections show high uncertainty, with large differences across future scenarios and between climate models. This uncertainty is analysed in the study.
- The climate projections were used in a well-known crop simulation model, the Decision Support System for Agro technology Transfer (DSSAT) to assess the future impacts of climate change on agriculture. The results showed a distributional pattern across the country, with large negative impacts in the Terai, but a mixture of impacts and benefits at higher elevations.
- In the longer term (the 2070s), the models estimate net agricultural losses in Nepal. These direct losses are equivalent to around 0.8%/year of current GDP.
- These impacts could be more severe under some future climate scenarios/model projections, especially if there are changes in climate variability as well as average trends. However, impacts could also be lower under other futures, especially when increasing irrigation is taken into account.
- A number of additional potential effects from climate change are highlighted, including higher flood risks, enhanced soil erosion and changes in the range/prevalence of pests and diseases – these would all be likely to increase impacts to the agricultural sector.
- The study has also considered the future impacts of climate change on the hydroelectricity sector, using linked scheduling and power generation investment models, with the VALORAGUA and WASP (Wien Automatic Simulation Planning Package) models.

- The study considered two alterative climate model projections for this analysis, which were input into hydrological models to consider changes in river flows.
- The first run projected a decrease in low river flow during the dry season, which increases the capacity required for the system to meet electricity demand, increasing investment costs. The additional investment needed (from now to 2050, above the future investment baseline) was estimated at a total of US$2.6 billion in present values (pv).
- However, the second run projected an increase in low river flow, i.e. a benefit, reducing investment costs relative to the baseline by an estimated US$0.2 billion (pv).
- While there are potentially large impacts on the hydroelectricity sector, the analysis highlights that future effects are uncertain. There is therefore a need to consider uncertainty in future sector planning.
- A number of other potential impacts were identified for the sector, though not modelled, including the risks of increasing high flows and floods, the impacts of glacial-melt rates on river flows, and the risks of Glacial Lake Outburst Floods (GLOFs) on hydroelectricity infrastructure.
- Finally, the climate projections were used to consider the impacts of future climate change on water-induced disasters, using alternative climate model projections and hydrological models.
- These show potentially large impacts, though changes vary between catchments and with climate–hydrological models. In most cases, however, climate change was projected to increase the intensity and frequency of high flows, and increase flood risks in Nepal.
- Detailed analysis in two different river basins suggests that climate change could increase current high river flows by 20–100% by mid-century (2040s).
- At the same time, the return period of a flood of a certain magnitude is found to reduce significantly, such that the flow associated with a 1-in-10 year event could happen every few years under climate change, and a 1-in-100 year event could occur every few decades.
- An indicative analysis of the impacts of climate change on water-induced disasters at the national level estimates that the additional average expected annual direct cost could be equivalent to 0.6–1.1%/year of current GDP by mid-century (over and above existing damages), with an upper estimate of almost 3%/year.
- These increases in future impacts would also lead to additional indirect and macro-economic costs.
- Overall, the study concludes that the economic costs of climate change in Nepal for these three sectors could be equivalent to 2–3% of current GDP/year by mid-century.

Adaptation can reduce these impacts, but requires an iterative approach

- Adaptation can reduce these impacts of climate change, but it has a cost. Large resources are likely to be required to address the existing adaptation deficit, as well as to prepare for future climate change.
- While there is uncertainty associated with future climate change impacts, this is not a reason for inaction. However, it does require an adaptive management framework (iterative climate risk management).
- This study has applied such a framework. It starts with addressing the current adaptation deficit, then considers the mainstreaming of resilience in development and finally considers long-term future climate change and uncertainty.
- A number of early priorities for adaptation are identified to address the existing adaptation deficit and build resilience. These focus on capacity building and 'low and no regret' adaptation options.
- The study then undertook a climate risk screening and investment and financial flow analysis to assess the potential costs of building resilience into development and sector plans (mainstreaming). This showed that the Government of Nepal is already taking action to build resilience, though a major increase in adaptation investment is needed.
- The additional investment to build resilience in current/future plans in the three risk areas (agriculture, hydroelectricity and water-induced disasters), from now to 2030, was estimated at a total of US$2.4 billion (pv).
- The study also identified the major long-term challenges from future climate change and the early actions needed to address the long-term risks as part of iterative adaptation plans.

Recommendations and next steps

- A number of priority areas for future consideration and research are set out in the report. The most important include the need to: build capacity and enhance research and monitoring; scale up the implementation of early 'low and no regret' adaptation measures; design and implement sector adaptation investment plans (aligned to iterative pathways); and start early programmes for the critical first steps to address long-term climate change.

Introduction

At the request of the Government of Nepal, the Climate and Development Knowledge Network (CDKN) funded this study on the 'Economic Impact Assessment of Climate Change in Key Sectors in Nepal'. The work was led by the Integrated Development Society Nepal (IDS-Nepal), working with Practical Action Consulting (PAC) in Nepal and the Global Climate Adaptation Partnership (GCAP) in the UK.

The primary objectives of the study are:

- To provide headline and sectoral estimates of the impacts and economic costs of climate change for key risks in Nepal (agriculture, hydroelectricity and water-induced disasters); and
- To identify climate compatible development adaptation options which address these potential impacts.

This report provides a summary of the work. A technical report is also available at www.idsnepal.org.

Baseline Context

The study started with a country and context analysis in order to identify the key issues for the agricultural sector, hydroelectricity generation and water-induced disasters, and to identify where to focus the research.

The agricultural sector accounts for around three-quarters of employment and around one-third of Gross Domestic Product (GDP) in Nepal. The sector is predominantly made up of small-scale farming and much of this is dependent on natural rainfall, though there is a growing level of irrigation. Historically, the agricultural sector has been heavily affected by floods and erratic rainfall, although there have also been droughts in recent years.

Water is critical for Nepal's power production as hydroelectric plants provide around 90% of total electricity. Rainfall has a major influence on generation, affecting run-of-river plants (i.e. those without storage reservoirs) as well as reservoir levels. During the dry season, river flows are insufficient to operate all plants, which results in high levels of planned interruptions (often referred to as 'load shedding' in Nepal), compounding existing problems of unmet demand. Current electricity outages have high costs for Nepal's industrial production, and planned outages are likely to continue during the dry season at least in the short-term. These impacts are important as there are plans to develop further capacity in the future and the sector is seen as a major source of growth and exports.

Nepal is also frequently affected by water-induced disasters. Flood inundation is the major climate-related hazard in the country, affecting property, agriculture, infrastructure (roads, bridges, communications and transmission networks), business and commerce and, at worst, causing loss of life. Landslides – which are often related to extreme rainfall or flood events – can also have significant impacts on communities and infrastructure. Floods are particularly associated with summer monsoon rains, and are a feature of current climate variability. There are also additional risks from Glacial Lake Outburst Floods (GLOFs) which can impact on communities and infrastructure for considerable distances downstream.

This baseline information reveals that Nepal already experiences high impacts from current climate variability, and future climate change has the potential to exacerbate these risks as well as introducing new ones. This study has therefore undertaken a detailed assessment of the potential impacts of climate change and the associated economic costs in the three areas (agriculture, hydroelectricity and water-induced disasters), and looked at potential adaptation responses.

Methodology

Recently, the climate change literature on vulnerability, impacts and adaptation has changed. The latest studies focus on early decisions, rather than on long-term changes alone; and now also consider uncertainty. As highlighted in the recent reports from the Intergovernmental Panel on Climate Change (IPCC)[1], this requires a shift in countries' planning to include adaptive management (iterative climate risk management).

At the same time, as adaptation moves towards implementation, there is a need to integrate (mainstream) climate change in the context of national development objectives and sectoral plans. This requires the analysis of impacts over time, with different targeted adaptation responses that more closely relate to current policy.

The method used in this study recognises these changes and has developed an iterative and dynamic

1 IPCC WGII (2014) IPCC WGII Summary for Policy Makers. Impacts, Adaptation and Vulnerability. IPCC.

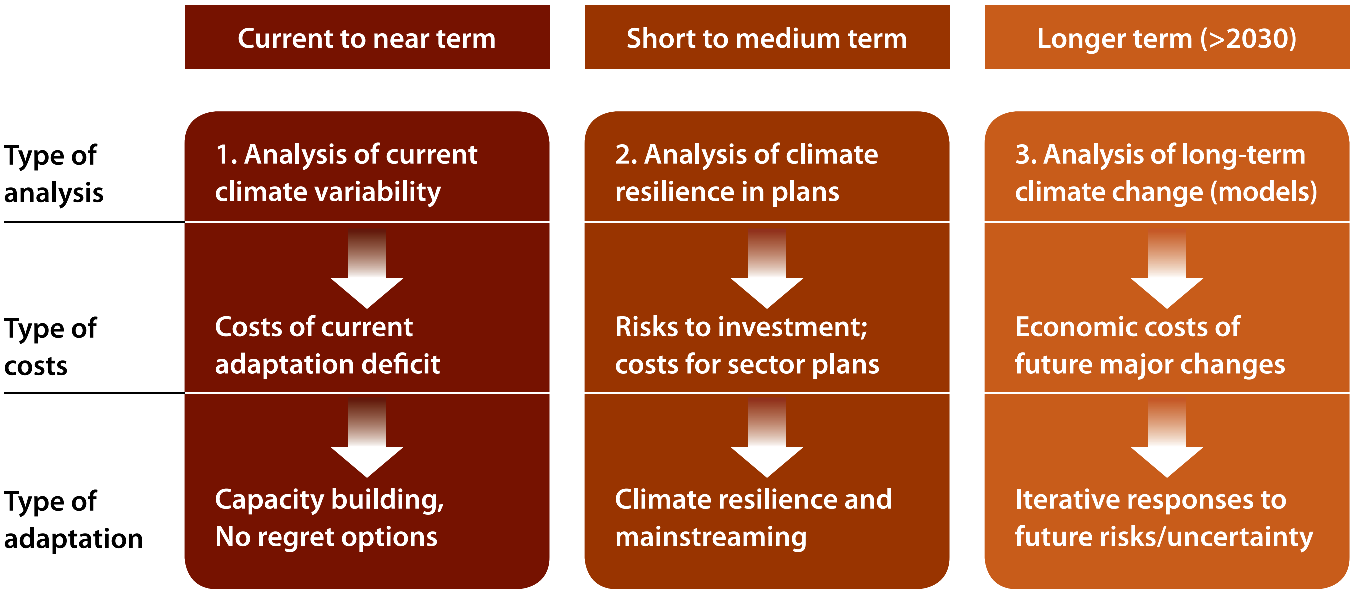

Figure 1. Project methodology. Source: GCAP

methodology, shown in Figure 1. This has three major steps that are brought together in an impact–adaptation pathway.

First, the analysis starts with the impacts and economic costs of current climate variability and extreme events today – often referred to as the 'adaptation deficit'. This recognises that adaptation to future climate conditions is less likely to be effective if current adaptation deficits are not also addressed. In response, it considers options to reduce this deficit and also build future resilience, focusing on 'no and low regret' options and capacity building.

Second, it considers the potential risks of climate change in the next few decades (e.g. to 2030) to development and sector plans, grounding the analysis in policy with a risk screening and investment and financial flow analysis. It then considers the additional activities and resources needed to mainstream climate change into development futures.

Finally, it considers the future impacts and economic costs of climate change in the long term (e.g. towards 2050 and beyond) using climate projections and impact models, including uncertainty. In preparation for these future challenges, it outlines iterative adaptation responses, identifying the early actions needed today to start planning for these future longer-term risks, i.e. within a framework of decision-making under uncertainty.

Capacity Building and Stakeholder Consultation

In undertaking the analysis, the project engaged and consulted with a wide range of stakeholders.

The project set up and reported to a Government Steering Committee, which met at key points in the project. This ensured enhanced capacity, ownership of the project outputs, and the integrity of the project in the context of national policy.

A series of stakeholder events and workshops were held with a diverse group of stakeholders. These were complemented with Technical Working Group meetings at key points in the project.

To help further build the capacity of local researchers, practitioners and government officials in carrying out and using economic climate change assessments, all tasks were undertaken by local and international teams working together. In addition, a series of training and information-sharing activities were held for local researchers and government officials.

The project also undertook a training needs-assessment across the Government of Nepal and, on the basis of the findings, designed and held a major a three-day training session with government officials.

The training was given by Nepali and international experts, with the aim of building the capacity of government officials and other key stakeholders.

This included training on the methodology and approaches to assessing the economic impacts of climate change, as well as how to use this information for adaptation strategies and wider planning.

The Impacts and Economic Costs of Current Climate Variability

Nepal has an extremely varied and complex climate, driven by the contrasting terrain and regional weather systems. Within a few hundred kilometres, the country rises from the flat Terai plains – with a low point of only 70 metres above sea level – to the top of Mount Everest (8,848 metres). This drives strong temperature gradients across the country, from the hot plains to the cold mountains, as shown by the temperature profile in Figure 2.

Nepal also experiences complex seasonal weather patterns, which are heavily influenced by the Himalaya, and include the annual monsoon. This leads to high rainfall variability across seasons and regions of the country, as well as between years.

The complex existing climate of Nepal means there is high climate variability and extreme events are common. The study considered the impacts of these.

Water-induced disasters, notably floods (in the plains) and landslides (in the hills), associated with the monsoon rains, are the most common natural weather hazard in Nepal. These events lead to the loss of life and cause major damage to property and infrastructure. They also have major impacts on livelihoods, affecting tens to hundreds of thousands of people every year.

The study assessed historical information on floods and landslides over the last 30 years and built up an analysis of the economic costs of these events, as shown in Figure 3. To provide a more comprehensive analysis, the costs include damage to buildings and infrastructure as well as the economic costs of the events in terms of people's health and welfare. The estimated direct economic costs of these historical events have been very large, equivalent to 1.5% of current GDP/year on average (approximately US$270 million in 2013 prices).

These include major events from time to time, which have much higher costs. Indeed, in exceptional years (e.g. the floods of 1993) the economic costs of extreme events and variability have been 5% of GDP equivalent or more.

These events also lead to indirect effects which arise as a consequence – e.g. business disruption, lost wages and macro-economic costs – from the effects of major disasters on consumption, inflation and the shift of resources to relief and reconstruction. As a broad indication, these issues would increase the costs reported above by 25–100%.

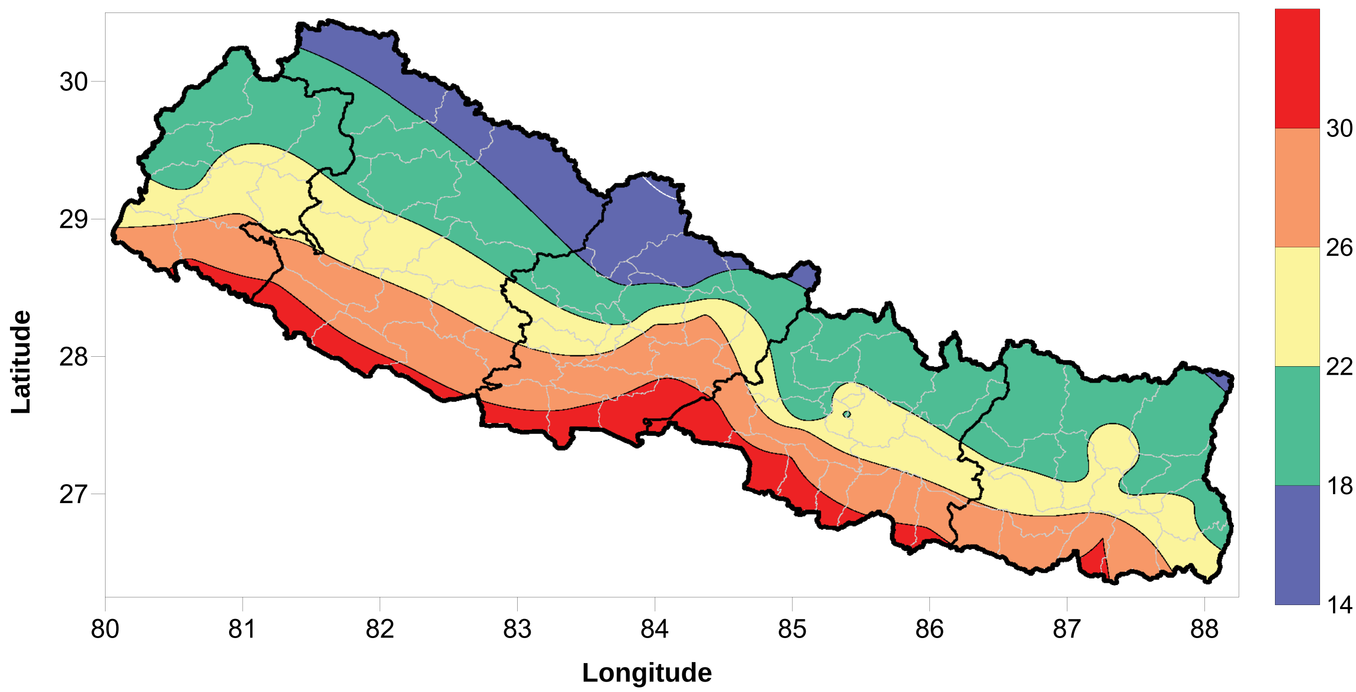

Figure 2. Spatial variation of mean maximum temperature (°C). Source: Practical Action [2009] Temporal and Spatial Variability of Climate Change over Nepal (1976–2005).

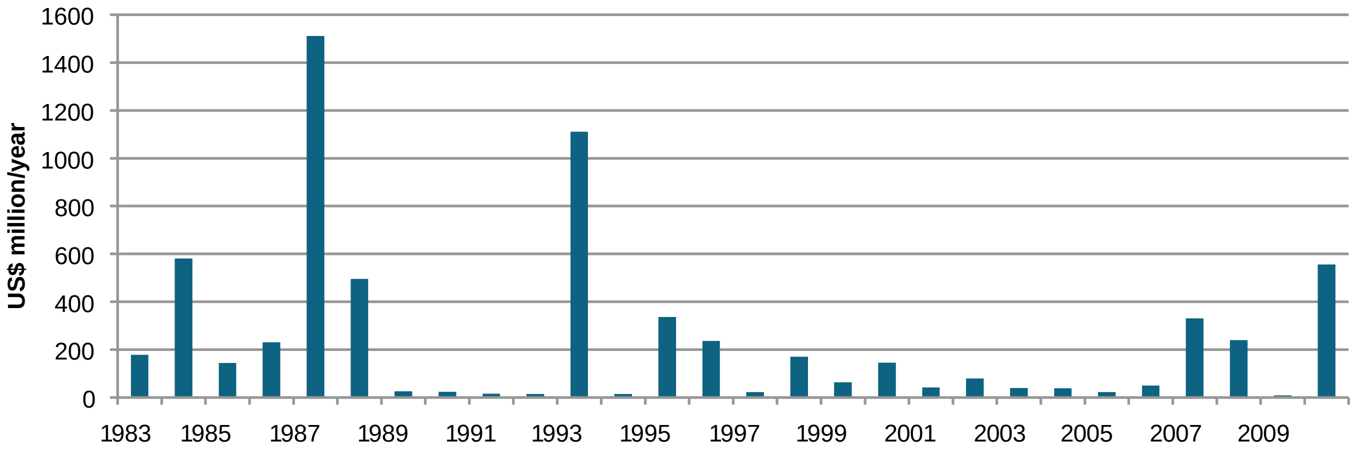

Figure 3. Economic costs (national) of water-induced disasters (flood and landslide) in Nepal 1983–2010
Includes infrastructure, property and health damages, based on data from the Department of Water-Induced Disaster Prevention, Nepal; 2013 prices.

Current climate variability also affects Nepalese agriculture, which is predominantly small-scale and heavily dependent on natural rainfall, leading to large annual variations in production. As well as floods, Nepal also experiences periodic droughts, which have large impacts on the sector.

The economic costs of major droughts are large. These events occurred most recently in 2006 and 2009 and the study estimates the direct economic cost of these (from lost agricultural output) was equivalent to 1.9% (2006) and 0.4% (2009) of current GDP. As with floods, the health and welfare losses associated with food insecurity, along with the additional indirect and macro-economic effects, would increase these direct costs further.

Nepal also experiences natural hazards in the form of GLOFs. While the damage and loss of life from these events are important locally, historical events are low (in terms of fatalities and damage costs) when compared to the national flood damages reported above. This is because of the low frequency of GLOF occurrences (there have been seven major GLOFs over the past fifty years) and also because they have had a more limited geographical extent.

Nepalese agriculture in the hills and mountains is also affected by soil erosion due to the steep gradients and intense monsoon rainfall, leading to reduced soil fertility and declining agricultural productivity. While it has not been possible to quantify current losses, the cumulative effects are likely to reduce annual agricultural production by several percent in the cultivated areas of the hills and mountains.

Finally, current climate variability also affects hydroelectricity generation. The seasonal variation in rainfall means that a number of run-of-river plants do not operate at the desired or planned capacity during the driest months of the year (January, February, March and April). This leads to planned rolling blackouts (engineered supply interruptions) to consumers, often referred to as 'load shedding' in Nepal. These power interruptions have high economic impacts, especially in low rainfall years where they can also reduce storage reservoir recharge (which occurs during the monsoon). An analysis of the impact of climate variability on electricity production (and the impact of planned interruptions) indicates that economic costs could be equivalent to 0.1% of GDP per year on average, and 0.3% in very dry years. Hydroelectric plants are also subject to the risks of floods including, in some locations, GLOFs. Indeed, a multi-million dollar hydro-power facility was lost in 1985 due to a GLOF event and there have been more recent losses of micro-hydro plants from floods.

The analysis shows that the direct economic costs of current climate variability in Nepal are very high, even for the three areas considered (agriculture, hydroelectricity, water-induced disasters). These impacts also have a major influence on livelihoods affecting hundreds of thousands of people in extreme years. They lead to high economic costs, estimated at 1.5% to 2% of current GDP equivalent in an average year (approximately US$270–360 million/year in 2013 prices) and as high as 5% in extreme years. These damages are dominated by water-induced disasters. When indirect and macro-economic costs are added, the total costs are likely to be 25–100% higher.

These results compare to average natural disasters losses of around 0.3% of GDP for low-income countries.[2] This shows that Nepal has a high existing

2 IPCC (2012) Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

Box 1. Case Studies

While the study has focused at the national level, there is a high degree of spatial variation in impacts across the country, reflecting differences in climatic and agro-ecological zones.

Importantly, there are also large differences in the distribution of impacts across groups in society (by gender or income level). Three local case studies were undertaken to complement the national level focus and explore these issues, as well as capturing community-based perceptions of recent climate trends. These used household surveys, focused group discussions and key informant interviews.

Hail Storms in the Kaski District

Hail storms are an important impact of current climate variability affecting the agricultural sector, but are not captured in most assessments of current impacts and recent trends. To investigate these impacts, the study carried out a case study undertaking new household survey work in the Kaski District – an area which is particularly affected by these events.

The case study found a strong community perception (around 80% of households surveyed) that hail storm events had been increasing in frequency and intensity. Based on communities' recollection, around 20 major hailstorm events had occurred over the last 35 years, causing significant damage to crop production (damaging 50–100% of key crops), livestock and infrastructure (including water tanks, pipelines, and window panes). Communities also mentioned that while relatively rare, deaths and injuries to people had occurred.

In the communities studied, 85% of households now use plastic tunnel farming or greenhouses to address the problems of hailstorm damage (an autonomous adaptation response). They have also started to change cropping patterns partly to cope with the hailstorm events, but also to increase income through cash crops. Looking forward, climate change has the potential to change extreme rainfall, which is a factor in hailstorm formation, and thus these types of events are relevant in terms of potential future impacts.

Flooding in the West Rapti River Basin

The second case study investigated flooding in the West Rapti River Basin – one of the most flood-prone areas of Nepal – with surveys in the Banke District. This found that nearly all households had experienced agriculture losses (around 60%) in major flood years as well as an increase in waterborne diseases after these events. The impacts of floods were found to have strong distributional differences, with the highest impacts on children and poorer females. For women, many of these impacts arose post event, e.g. associated with health impacts and difficulties looking after themselves and taking care of their children.

The majority of households (73%) believed that the frequency of flooding events had intensified over the last decade. In response, those who could afford it had reinforced the foundations of their homes or raised the plinth of the house. Some had intentions to migrate. Others had changed their cropping systems or patterns. All of these are forms of household-level adaptation. While there are now community-level emergency response plans and an early warning system, these were only partially effective. Looking forward, the anticipated increase in flood risks from climate change has the potential to exceed current coping capacity, and is likely to necessitate more extensive planned responses.

Buckwheat Farming in Mustang

The final case study focused on the effects of recent changes in climate on farming in Mustang – a semi-arid part of the mountainous agro-ecological region of Nepal, and an area of high vulnerability. The case study focused on buckwheat, an important crop in the area and one that is grown by most households.

The household surveys reported a decline in the productivity of buckwheat over the last decade, with changes in climate considered an important factor in this decline. Looking forward, this highlights the potential effects of shifting climate–agro-ecological zones on many existing farming systems, and the need to enhance the capacity of local livelihood systems to adapt.

adaptation deficit by international levels, i.e. it is not adequately adapted to the current climate. This requires urgent action otherwise adaptation to future climate change will be less effective. Addressing the current deficit will also lead to immediate economic benefits and is thus a priority.

The estimated direct costs of current climate variability are equivalent to 1.5–2% of current GDP/year in Nepal.

A key conclusion is that the country has a large existing adaptation deficit.

Future Climate Change

The analysis of recent observational data shows that the climate of Nepal is already changing. Temperatures have increased rapidly over recent decades, at a much faster rate than the global average. There have been changes in precipitation as well, including heavy rainfall, though the trends are more complex and show wide variations across the seasons and the regions of the country. There are also changes observed in Nepalese glaciers, some of which are retreating and thinning.

These trends are anticipated to increase with future climate change, and the study analysed climate model projections to asses these changes and subsequent impacts. The study considered regional climate model outputs and statistically downscaled climate information, both of which have higher spatial resolution. However, undertaking climate assessments in Nepal is very challenging due to the complex climate and the large elevation gradient across the country. As a result, only a small number of regional climate models have been run.

The study primarily used the climate modelling results produced by the Indian Institute of Tropical Meteorology (IITM), which used the PRECIS model (Providing REgional Climates for Impacts Studies) driven by the HadCM3 global circulation model (GCM). This provided bias-corrected outputs for the A1B scenario: a medium-high emission scenario that does not consider global mitigation. Further details are provided in the technical report.

The results of this projection show rapid increases in temperature across the country under climate change, with average maximum and minimum temperatures increasing by 3–5°C by the end of the century (relative to the baseline period). The changes in precipitation are more varied, with high spatial and temporal differences. Depending on the future time period and the region of the country, there are differences in whether increases or decreases in average rainfall are projected, though there is a general trend of increasing extreme precipitation.

The climate of Nepal is already changing due to climate change, with increasing temperatures and changes in rainfall patterns in recent decades.

However, this only considers one climate scenario, run with one model: there is considerable uncertainty between different future scenarios and alternative climate models (see Box 2) which is relevant for assessing future impacts.

To address this, a detailed uncertainty analysis was undertaken in the study, comparing different regional climate model runs as well as statistical downscaled datasets (which adjust global modelling results based on local meteorological station observations). Subsequently, for the water sector analysis different climate model outputs were used, comparing the IITM runs to a second A1B projection using the PRECIS model, but with the European Centre Hamburg Model, ECHAM5, as an alternative driving GCM.

The uncertainty analysis found a consistent warming trend, but with variations in the level of warming across scenarios and models. However, it found large differences in the projected changes of future rainfall across climate models, seasons and locations, even in terms of the sign of change. The subsequent changes in river flow are further affected by the (uncertain) effects of climate change on glacial ice reserves and meltwater, which may increase river flow in the short-term but reduce it in the longer term, at least for some rivers.

The consideration of this uncertainty is critical in analysing future impacts of climate change, and for planning adaptation responses. It cautions against the use of central projections. However, this is not a reason for inaction. Instead, it highlights the need to recognise uncertainty in planning any adaptation response, using iterative strategies that allow learning and updates over time.

Alongside the future projections of climate, the study also considered strong socio-economic changes, noting these are likely to be as important as climate change itself for future impacts. There is

Box 2. Analysing Climate Model Uncertainty

An example of the uncertainty in the climate model projections for Nepal is shown in Figure 4. The figures show the change in monthly rainfall with climate change over the months of the year (January to December) for six different locations across the country, based on statistically downscaled results for the middle of the century. Each figure shows the change in monthly rainfall relative to the current baseline (which is shown by the central line). The blue columns show the range of change across nine different climate models. While the general pattern is similar – with an increase in precipitation during the monsoon months – there is by no means agreement across all the models. Indeed, looking across the months of the year and the different regions it can be seen that, in some cases, some models project decreases in rainfall (below the central line) while other project increases. It is important to consider this uncertainty in analysing impacts and adaptation.

This uncertainty is not a reason for inaction, but it does highlight the need to use iterative response strategies that allow learning and updates over time.

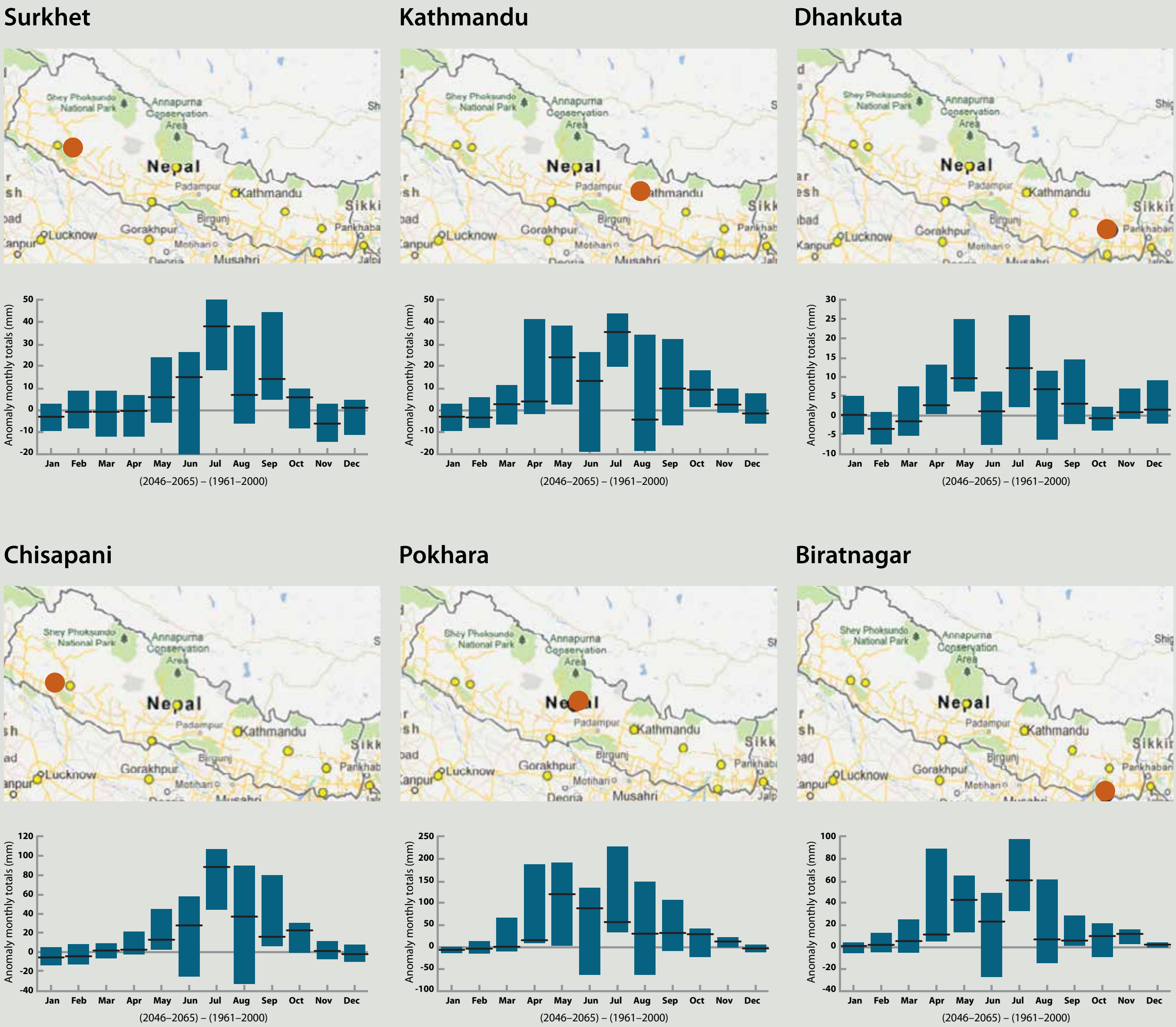

Figure 4. Monthly rainfall for the mid-century projections (A2) for different sites across the country
Source: Cimate Systems Analysis Group, University of Cape Town, 2012

high population growth projected for Nepal, with an increase from 30 million today to around 35 million by 2020, 40 million by 2030, and 46 million by 2050. This will increase demand on land-use, natural resources and water, and it will also increase the number of people at risk from the impacts of climate change. Economic growth in Nepal is projected to continue, with GDP projected to increase by a factor of five by 2030. While this will increase the assets at risk, economic development should build adaptive capacity and help reduce vulnerability.

Risk Screening and Climate Mainstreaming

The study then considered the medium term – i.e. the next couple of decades (to 2030) – focusing on the risks of climate change to development in Nepal. This places the analysis of impacts and adaptation within the institutional structure of government, and takes account of the existing programmes and policies. It also provides baseline information to assess future mainstreaming needs and adaptation investment, aligned to existing Country Development Plans.

The study undertook an investment and financial flow analysis – a form of Public Financial Management assessment. This looked at the current and future (planned) investment in each of the three sectors of interest (agriculture, hydroelectricity and water-induced disasters) and analysed the activities within the current baseline of 'on budget' programmes and activities, as well as 'off budget' activities funded by development partners and the private sector.

The study first considered the current budget in hydroelectricity, water-induced disasters and

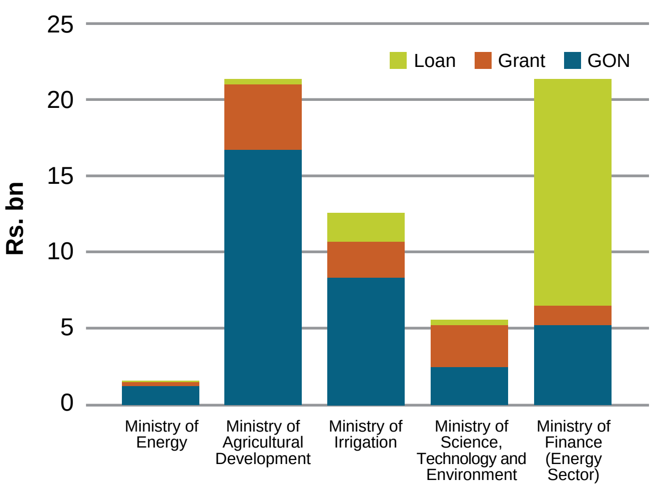

Figure 5. Source of finance by ministry 2013–14 (in billion rupees)

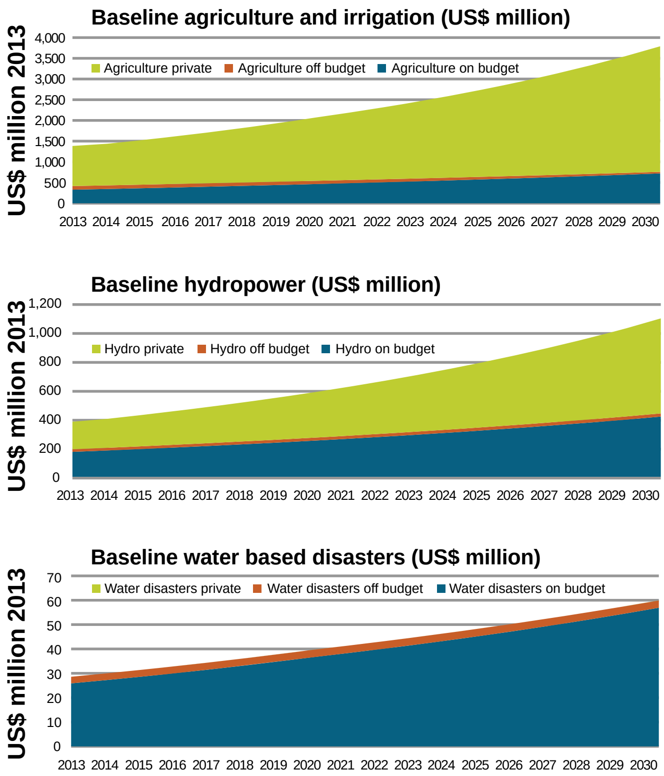

Figure 6. Future investment baselines

agriculture (agricultural development and irrigation). The total investment (public, off budget and private) in these sectors in Nepal totals around US$1.8 billion/year, as shown in Figure 5, but this is dominated by agriculture.

Next, the study built a future baseline investment profile to 2030, as shown in Figure 6. For hydropower, total investment (including public sector, off budget and private sector) was projected to increase in real terms from US$390 million/year currently to US$1.1 billion/year by 2030,with a total investment of US$5 billion for the period 2014–2030 (discounted). For irrigation, investment was projected to increase from US$1.4 billion/year currently to US$3.8 billion/year by 2030, with a total investment of US$17 billion for the period 2014–2030 (discounted).

Finally, for activities that address water-induced disasters, investment was projected to increase from US$29 million/year currently (on river management, watershed conservation) to US$60 million/year by 2030, with a total investment of US$321 million for the period 2014–2030 (discounted).

Overall, there is projected to be continued high investment and growth in agriculture, along with a much higher relative increase in hydropower investment. The planned investment in water-induced disasters is lower, reflecting the dominance of state and development assistance funding (for this public good).

Sector	Policy	Explicit climate change objectives	Implicit climate resilience benefits
National Development	National Three Year Plan (2010–2013)		
Water cross-cutting	National Water Strategy (2002)		
	National Water Plan (2005)		
Agriculture and irrigation	Draft Agriculture Development Strategy (2012)		
	Climate Change Adaptation: Priority Framework for Action (2011)		
	National Agricultural Policy (2004)		
	Irrigation Policy (2003)		
Hydropower	Rural Energy Policy (2006)		
	Hydropower Development Policy (2001)		
Water disasters	Water Induced Disaster Management Policy (2006)		
	National Strategy for Disaster Risk Management in Nepal (2008)		

Explicit climate resilience objectives

- Does not explicitly recognise climate risks in policy development
- Explicitly recognises current climate risks to policy development
- Explicitly recognises future climate change with policy response

Implicit climate resilience benefits

- Activities deliver minimal or no climate resilience benefits
- Activities likely to build resilience to current climate risks
- Activities provide resilience for increased risk scenarios in future

Figure 7. Assessment of climate readiness of key policies and strategies

The analysis then reviewed existing policies and plans, to assess the potential risks of climate change to these plans and examine whether climate resilience was already being mainstreamed. The aim of this climate risk screening was to assess the level of 'climate readiness' of the current policy framework and to identify opportunities for mainstreaming. The results are shown in Figure 7.

A key finding was that the Government of Nepal is already integrating climate change into its Three-Year Plan, and has developed a strong package of national-level planning frameworks such as the supporting climate change strategies (National Adaptation Programme of Action, Local Adaptation Plan for Action, Strategic Program for Climate Resilience/Pilot Project for Climate Resilience, and the Climate Change Policy).

However, the progress in mainstreaming at the sector-level was more varied. Strong progress has been made in the agricultural sector, where the Priority Framework for Action and the draft Agricultural Development Strategy both put climate resilience at their core. However, in other sectors (hydropower and water-induced disasters) there has been less mainstreaming for current and especially future risks, though many of the policies in the water sector implicitly promote activities that support resilience. The analysis also identified priority areas in need of strengthening and identified climate considerations for analysis of future adaptation.

Future Climate Change Impacts and Economic Costs

The third and final work stream assessed the future impacts of climate change in the longer term. This used scenario-based impact assessments, with downscaled climate model projections and sector impact models.

Agriculture

The analysis of the future impacts of climate change on the agricultural sector focused on the key crops grown in Nepal – i.e. maize, wheat and rice – using the Decision Support System for Agrotechnology Transfer (DSSAT) crop model.

Overall, the results of future climate change (for the A1B scenario) show a strongly differentiated pattern over time and across the country, with potentially high impacts in the Terai (especially for rice and wheat production), but a varied pattern in the hills and mountains that include some potential benefits.

In the Terai, the yields of some key crops are projected to decrease by 10–20% with climate change by the 2070s, leading to large impacts on national production. The study also assessed the changes in productivity and valued these to provide an overall analysis of the changes.

In the 2030s, the impacts of climate change on agriculture are mixed with the potential for even an overall net increase in production. However, as shown in Figure 8, by the 2070s, climate change leads to a net decrease in crop productivity and high economic costs from lost production, estimated at US$140 million/year (current prices, undiscounted), equivalent to around 0.8% of current annual GDP.

The negative impact of food production potentially increases food insecurity for vulnerable groups, and has possibly high distributional effects, including on women.

These estimates report the average results: in extreme years the effects will be much more severe. The study also found some indications of increasing rainfall variability in later years, which could lead to major impacts. However, these results do not take account of irrigation and farm-level adaptation (e.g. crop switching), which would reduce impacts.

A number of other impacts were also highlighted for future consideration, including increased flooding, increased soil erosion and the changing range and prevalence of pests and diseases, all of which are expected to have negative effects.

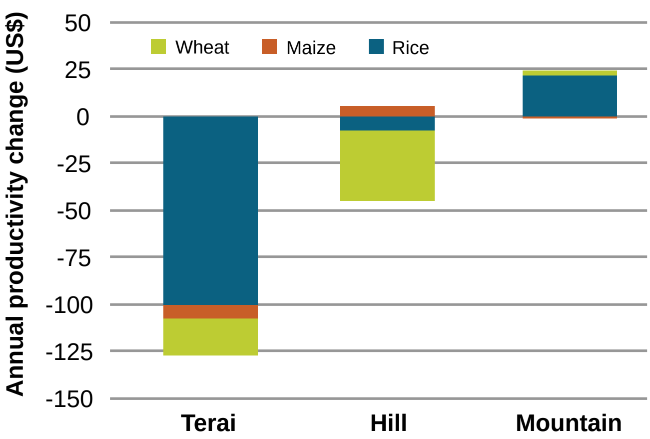

Figure 8. Annual productivity changes (US$ million, 2013) from climate change in the 2070s

Finally, the analysis of uncertainty revealed potentially large differences in future climatic variables which translated into a wide range of possible impacts on the sector. This included more modest or positive outcomes (e.g. when average rainfall increases) but also much more severe impacts (e.g. rainfall reductions or greater variability).

Hydroelectricity generation

The analysis of the future impacts of climate change on hydroelectric power used hydrological models to link climate outputs with changes in river flows which, in turn, were used as inputs to a hydroelectricity optimisation modelling system (comprising the Valoragua model and the Wien Automatic System Planning model (WASP)). The analysis considered changes in dry season flows and the operation of run-of-river plants, as well as the effects of rainfall and river flows on reservoir storage recharge.

The results were used to consider the effects of climate change on electricity generation, and thus on the future plant investment profiles needed to meet future electricity demand in Nepal. However, the analysis of river flows with climate change was very challenging due to the complex nature of Nepal's climate, the uncertainty in rainfall projected by the climate models and its translation into daily river flows, and the additional uncertainty from glacial meltwater. The study found large differences projected by the climate models; thus the analysis compared two different model outputs.

The first model projected lower dry season flows and thus lower energy availability. An example is shown in Figure 9. The additional generation capacity needed to meet future demand under this scenario, due to climate change, was estimated at 2,800 MW (by 2050) with an increase in costs of US$2.6 billion (present value) for the period through to 2050, relative to the baseline. This indicates a high economic impact from climate change and and also additional thermal plants on the system, increasing greenhouse gas emissions.

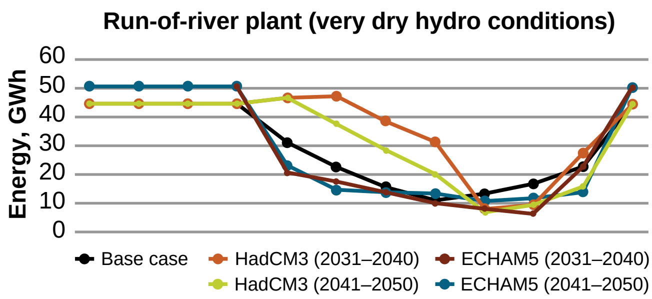

Figure 9. Available energy from run-of-river plants with climate change

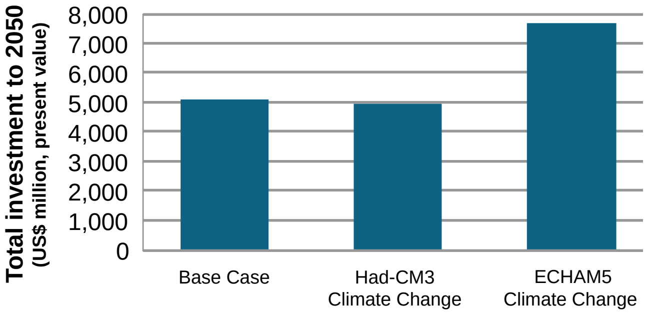

Figure 10. Total investment: current to 2050 (present value)

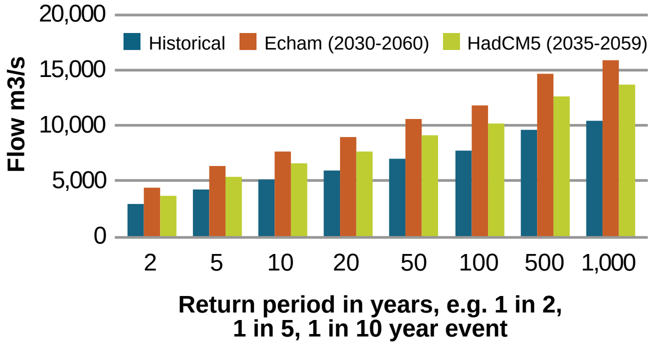

Figure 11. Change in return periods for two alternative climate model simulations for the future (mid-century) – for the Tamor River at Mulghat

However, the second model, which projected higher river flows in the dry and wet seasons led to increased energy availability with climate change. This scenario avoided the need for additional power, even relative to the baseline, with an estimated reduction of generation expansion costs of US$170 million (present value) over the period to 2050 (i.e. a benefit).

The results indicate that the potential importance of climate change on the sector is high, but that there is considerable uncertainty over future changes, which vary by climate model (as shown in Figure 10), river catchment and over time. It is highlighted that using historic data for the design of plants will not capture these possible future changes. This necessitates more monitoring and research, and a move to more flexible and iterative planning.

A number of other impacts are also highlighted for future consideration, particularly the increased risks of GLOFs. These could have potentially high impacts on the sector, and are an important factor in the design of plant and future sector planning.

Water-Induced Disasters

The analysis of the future impacts of climate change on water-induced disasters focused on the increase in high flows and flood events, using climate and hydrological models.

Data for two different river catchments (the Tamor and Bagmati rivers) was used to assess the potential future impacts of climate change. The results were analysed to look at two inter-related questions. First, how will the frequency of current return periods alter with climate change, i.e. for a high flow event that happens once every 10 years now (as a historical average), and what will be the future return period for that same flow with climate change? This provides information on how much more frequently such an event will occur. Second, how much will the magnitude of a given high flow increase by, i.e. how much bigger is the 1-in-10 year flow event under climate change and how much might this increase damages?

To do this, the analysis looked at the change in frequency and intensity of high river flows, and thus the risk and impacts/damages of flooding (i.e. the shift in the probability–loss relationship). The results showed the intensity and frequency of high flows – and thus water-induced disasters – increases significantly with climate change, even by mid-century (2040s). An example is shown in Figure 11.

The change varies with the river catchment and the climate/hydrological model used; but, as an example, the increase in current high flows (intensity) associated with flood events (e.g. a 1-in-10 year event) were estimated to increase by 20–100% by mid-century (2040s) due to climate change. At the same time, the return period of an event that currently occurs once in every 10 years was estimated to occur once in every five years (or less) with climate change. Perhaps of more concern, the probability of very major events, such as a current 1-in-100 year event, was found to increase and thus occur much more frequently.

An analysis of the direct economic costs of these changes estimates the additional direct costs of climate change at US$100–200 million/year (current prices, undiscounted), which is equivalent to 0.6–1.1% of current GDP. The total costs (including indirect and macro-economic costs) are likely to be 25–100% higher. However, there is considerable uncertainty and the changes could be much larger, with an upper estimate of almost 3% of current GDP/year.

These values assume static socio-economic trends. The population and assets at risk will increase significantly in Nepal: the population alone is projected to increase by over 30% by 2030 and GDP is projected to rise five-fold. These changes could increase economic costs by increasing people and assets at risk. However, economic development is likely to increase adaptive capacity and increase resilience, provided future risks

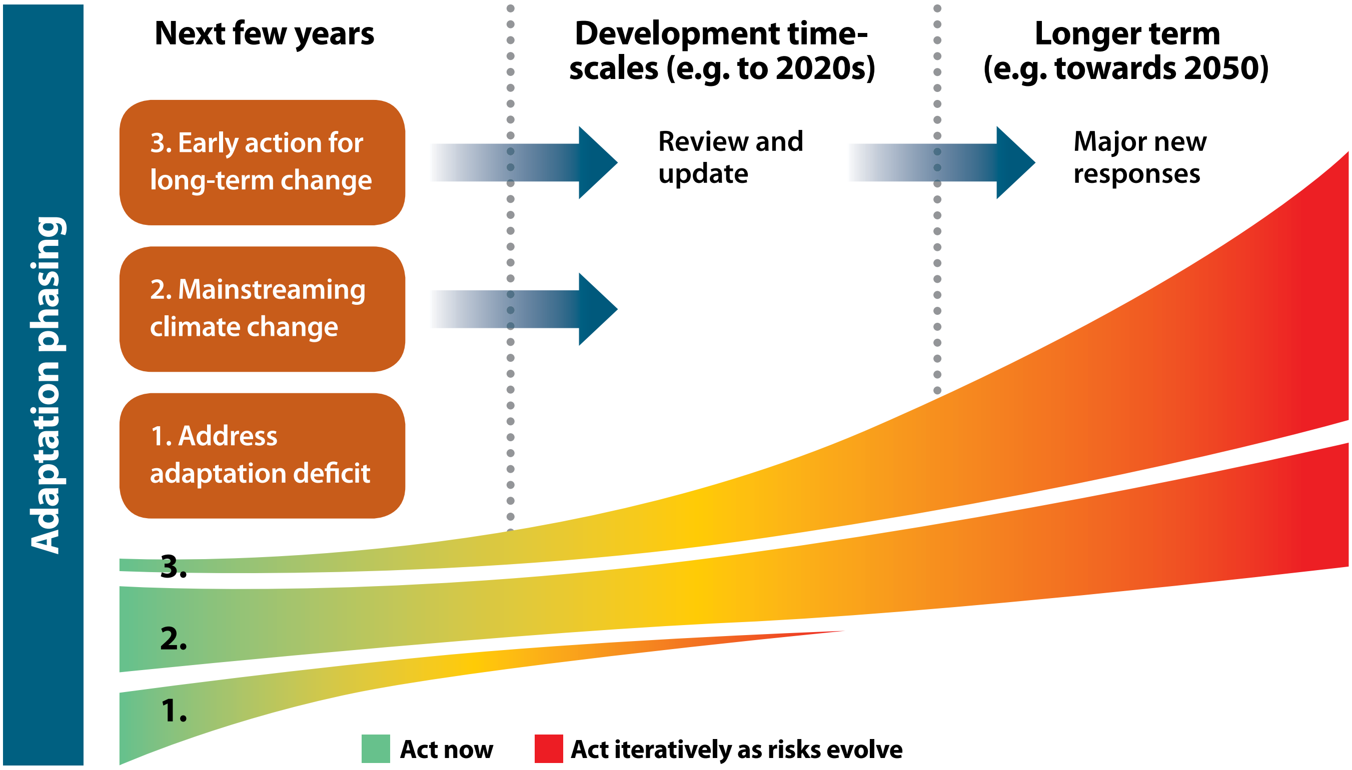

Figure 12. Adaptation pathway. Adapted from Watkiss, P. and Hunt, A. (2012) Method for the UK Adaptation Economic Assessment (Economics of Climate Resilience). Final Report to UK Defra. Defra, UK.

are planned for. This highlights the need for early adaptation.

The increased incidence of flooding is also likely to increase sediment transport, resulting in a higher proportion of downtime for hydroelectricity plant maintenance. Glacier retreat, attributed to rising temperatures at higher elevations, is also considered likely to affect the flow regimes of rivers and increase the risks from GLOFs.

Finally, the study looked at the possible economy-wide costs from climate change. An analysis of input-output tables identified the main linkages between sectors. These showed potentially large links that would widen the impacts to other parts of the economy, especially for sectors that have agricultural and livestock-based inputs.

Overall, the study concluded that there are potentially high economic costs from climate change in Nepal. The direct costs from the three areas could be equivalent 2–3% of current GDP/year.

The future costs of climate change are potentially very large in Nepal, with estimated future annual impacts across the three areas equivalent to 2–3% of current GDP by mid-century.

Adaptation

The study then assessed potential adaptation options to respond to current and future risks. An initial review identified a very large number of potential options, totalling several hundred: this highlights the need to prioritise adaptation.

To do this, the study developed an adaptation pathway, which matched the three analytical steps and timescales. This is illustrated in the Figure 12. In summary:

- The pathway starts with current climate variability and identifies immediate options to address the existing adaptation deficit (1). This focuses on the identification of options that are 'no or low regret' (i.e. good to do anyway, even without future climate change) and capacity building. These have immediate economic benefits and build future resilience.
- The next set of activities (2) is associated with medium-term development timescales and focuses on mainstreaming climate change. This includes an assessment of the additional options and investment (in US$) to build resilience into future development plans, using investment and financial flow analysis.

- The final set of activities is associated with the major future risks towards mid-century. However, noting the uncertainty with these, the activities (3) are built up within an iterative plan that can be reviewed and updated as information on risks emerges. This includes the identification of early priority actions, i.e. the immediate actions that are needed today to plan for these future risks.

Addressing the current adaptation deficit

Starting with the existing adaptation deficit, a number of options were identified as possible priorities.

In the agricultural sector, these centred on enhanced agro-meteorological information and forecasting, farm-level adaptation (improved varieties, addressing post-harvest losses), capacity building, awareness-raising and institutional strengthening, and sustainable agriculture/climate-smart agriculture (e.g. soil and water management, conservation agriculture, agro-forestry, soil conservation and slope stabilisation, rainwater harvesting).

In the hydrological sector, early priorities were identified around the improved management and retrofitting of older equipment in current plants, with additional activities around demand efficiency (transmission loss reduction, end-use energy efficiency) to allow more time and information before future major investment plans are devised.

For water-induced disasters, early priorities were identified for enhanced weather and hydrological monitoring and forecasting, enhanced early warning systems, capacity building and governance, community-based adaptation and people-centred interventions (increasing the resilience of households and livelihoods).

Critical infrastructure resilience, ecosystem-based adaptation and integrated land-use and water management were also identified as cross-cutting early priorities for all three sectors.

Many of these early options are already included in existing policies and programmes, or have been piloted. Therefore, a priority is disseminating good practice and scaling-up. This requires supporting capacity building (information, awareness-raising and education, monitoring, institutional strengthening, research and pilots).

It is also highlights that there are barriers to the introduction or uptake of some of these early options, including opportunity or policy costs, and they are therefore unlikely to happen on their own. Consequently, there is a need to provide the necessary enabling environment (capacity, policy incentives, etc.) and planned support.

Mainstreaming adaptation

The study then considered the additional activities needed to build resilience in sector development plans in the medium term (i.e. to 2030). This built on the investment and financial flow baselines and climate risk-screening presented earlier, assessing the additional activities and finance needed for mainstreaming adaptation. This was based on analysis and discussion (with Government and other stakeholders) in each of the three sectors.

For hydroelectricity, the main additional risks related to the reduction in river flow during drier periods for run-of-river plants (and associated reduction in output) and the increase in high flows (which will mean facilities need to be planned with greater capacity).

Based on discussions and the analysis of the climate and hydrological modelling results, the total additional adaptation costs to build resilience into the planned future sector development is approximately US$500 million, (present value) above the baseline for the period of which US$200 million falls on the public budget.

For agriculture, the additional costs were associated with a wide range of programme investments for resilience strategies for agricultural development and irrigation plans. The additional adaptation costs were estimated at US$1.7 billion (present value) for the period 2014–2030, of which US$370 million falls within the public sector budget.

Finally, for water-induced disasters, the increased likelihood and intensity of flood events due to climate change indicates a more substantial increase is needed in resilience activities (and thus a higher relative increase above the baseline than for the agricultural or hydrological sectors).

The additional investment needs to mainstream adaptation is estimated to rise to US$295 million/year by 2020 and US$530 million/year by 2030.

The total additional investment (current to 2030) is estimated at US$2.4 billion (present value)

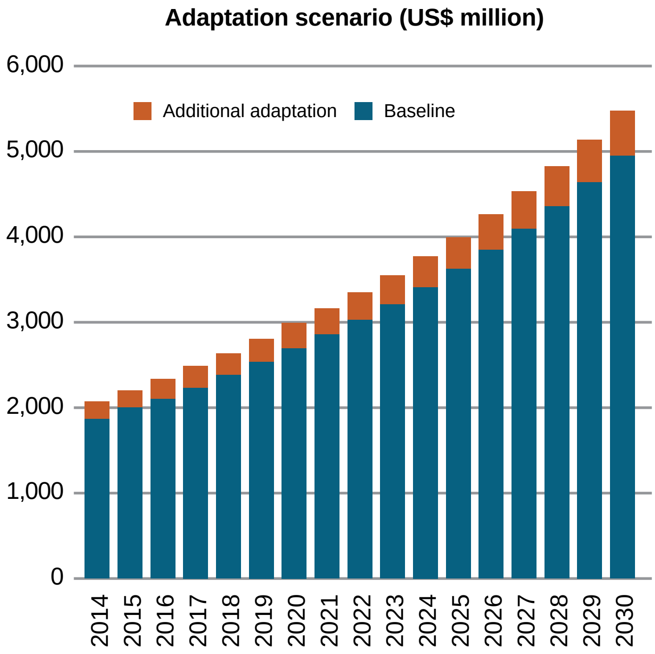

Figure 13. Adaptation investment needs

The total additional costs of adaptation for the water disaster sector were estimated at US$209 million (present value) for the period 2014–2030, of which the majority falls within the public sector budget.

The total additional adaptation needs for mainstreaming climate change in these sectors was estimated to rise to US$295 million/year by 2020 and to US$530 million/year by by 2030, as shown in Figure 13, with a total investment over the period (to 2030) of US$2.4 billion (present value, discounted). The increase above baseline investment is shown in the figure.

A sensitivity analysis was also undertaken to consider the uncertainty over future climate risks, using both a low (more modest) and high (more extreme) scenario – the latter implying almost a doubling of annual investment would be needed by 2030.

Importantly, the decision on which future pathway to adopt should be based on the learning over the next few years, consistent with the iterative risk management approach. This highlights the need for early capacity building and enhanced information and research over the next decade.

It is highlighted these future investment costs are indicative, as they are based on analysis of existing programmatic spending, key risks and the costs of possible interventions. The next step is to build detailed sector investment plans to assess detailed programmatic activities and costs.

Iterative plans and early activities (long-term)

Finally, the study considered the future major risks of climate change to Nepal in the longer term and, noting the uncertainty, developed initial iterative adaptation plans. These identified the short-term actions needed early-on, i.e. in the next few years, in order to build the evidence base to improve subsequent decisions and keep future options open.

For agriculture, the iterative plans centred on the long-term changes in agro-ecological zones, crop suitability and water use. An early identified priority is to build the response capability to respond to these emerging risks (as well as take advantage of potential opportunities). This includes enhanced monitoring of early changes, research and pilot-testing of promising options (especially given the time taken to implement major shifts). There is also a need for early analysis of future land-use and agriculture under climate change, and a priority for integrated water-resource management.

For hydroelectricity, a clear priority is for enhanced hydrological monitoring and research to better understand emerging trends, as well as to improve the information on the impacts of future climate change. In the short term, an early option is for infrastructure risk-screening, as well as pilots on improved design and enhanced flexibility, to ensure plans can perform robustly over future flow regimes (or have the potential to be upgraded to do so in the future). Under some future extreme scenarios, diversification strategies on smaller plant sizes could be justified, but these have high cost implications.

For water-induced disasters, enhanced early monitoring and research is again highlighted, with the use of this information in risk screening and integrated (sustainable) land-use planning, i.e. to avoid locking in development to future high risks from climate change. This will require enhanced planning and enforcement and, given the challenges in these sectors, early institutional strengthening is a priority. Early options in this area also include non-technical (ecosystem-based adaptation, watershed management) and the development of integrated flood-risk management.

Across all three sectors, the immediate priority is to build up more detailed iterative plans (including portfolios of options) and to identify and implement early programmatic activities (e.g. monitoring and pilot programmes).

Future Priorities

A number of priority areas for future consideration and research are set out in the technical report.

In terms of research, there are priorities for further work to understand climate and impact uncertainty as well as the indirect economic costs of impacts. There is also a priority to advance research to address the major long-term challenges of climate change. In addition, there is a need to consider the differentiated impacts of current climate variability (and future climate change) in the design of adaptation plans and programmes.

In terms of policy, the most important priorities are to scale up the implementation of early 'low and no regret' adaptation measures, to design and implement sector adaptation investment plans (aligned to iterative pathways), and to start early programmes for the critical early first steps to address long-term changes in climate.

Finally, to support all of these areas, there is an urgent need to build capacity, with information and awareness-raising, monitoring, research and institutional strengthening.

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