Climate Risk and Business

Practical Methods for Assessing Risk

IFC International Finance Corporation
World Bank Group

Acknowledgments

First printing, September 2010

Authored by
Vladimir Stenek, International Finance Corporation
Richenda Connell, Acclimatise
John Firth, Acclimatise
Michelle Colley, Acclimatise

IFC and the authors wish to thank the management and staff of Himal Power Limited, Ghana Oil Palm Development Company and Packages Ltd. for their support and cooperation in the elaboration of the studies. The authors also wish to thank the numerous local experts and institutions listed in Annex 3 for their valuable contributions to the studies.

This work benefited from support provided by the Trust Fund for Environmentally & Socially Sustainable Development (TFESSD), made available by the governments of Finland and Norway.

Reviewers
We thank the following for their critical review and comments: Peter-Martin Thimme (DEG - Deutsche Investitions- und Entwicklungsgesellschaft mbH) , Alan Miller, Jamie Fergusson, Susan Holleran, and Katia Theriault (IFC).

Editors
Rachel Kamins, Anna Hidalgo, Vladimir Stenek, Richenda Connell

Designer
Studio Grafik

Photo credits
Vladimir Stenek, International Finance Corporation
Chris Train, UK Environment Agency
Packages Ltd.

Climate Risk and Business

Practical Methods for Assessing Risk

Foreword

Climate change creates both risks and opportunities for the private sector, particularly in emerging markets. Climate impacts may affect companies' financial, economic, environmental and social performance, especially when they rely on long-lived fixed assets or have complex supply chains.

Yet to date, the evidence for the significance of these issues has been poorly defined. Most climate change assessments express impacts due to changes in a limited number of parameters, usually average temperature and precipitation, over large geographic areas and on relatively long time-horizons. However, private-sector needs include shorter time horizons, focused on smaller geographic areas and information about impacts that is specific to the business. Very few companies and private sector stakeholders, particularly those that are smaller in size, many of whom are in climate sensitive sectors, have the capacity and resources to produce such information.

Recognizing the gaps in knowledge of how climate change will affect the private sector and of the potential significance of the risks to investors, IFC undertook three pilot studies from 2008 to 2009, based on investments in developing countries. These studies aimed to understand gaps and barriers to private-sector climate risk analysis, to test and develop methodologies for evaluating these risks and, in this context, to identify possible adaptation responses and needs.

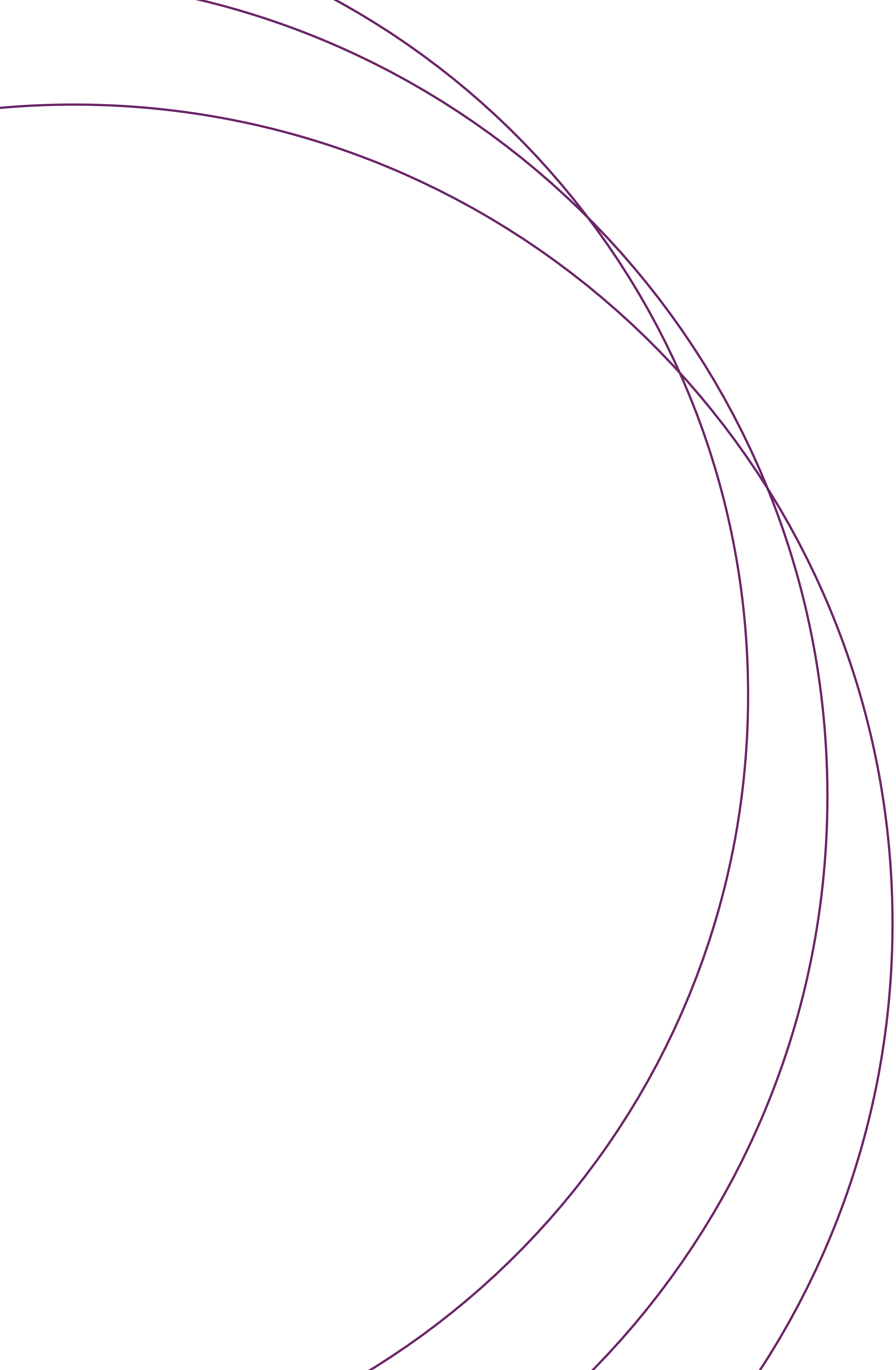
Despite the challenges and uncertainties inherent in undertaking such assessments, the studies have been able to generate new information related to climate risks to a variety of businesses across different locations. They have also demonstrated some of the practical approaches that can be applied by businesses to understand these risks better, to react as necessary, and to reduce uncertainty about the future. Ultimately, the ability of businesses like those studied here to adapt to climate change will depend not only on their own actions but also on the actions that may be needed from the public sector, non-government organizations, the scientific community and other stakeholders.

These pilot studies are an important first step in IFC's broader initiative to develop an understanding of the implications of climate change for business. IFC will continue to support this type of analytical work, which is critically important to helping our clients, and the private sector more broadly, to adapt to the challenges and opportunities brought about by climate change.

Rachel Kyte
Vice President, Business Advisory Services
International Finance Corporation

Table of Contents

Foreword



Introduction

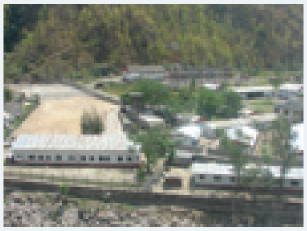
The main objective of the first set of pilot climate risk assessment studies undertaken by IFC was to test and begin to develop methods for evaluating climate risks to the private sector and to identify appropriate adaptation responses. This included analyzing barriers and gaps preventing evaluation of risks and adaptation options, and understanding the roles of different stakeholders (private and public) in addressing those constraints. The studies also aimed to provide information that reduces uncertainty about present-day and future climate-related risks to the pilot study clients. In this context, the pilot studies should be viewed as an initial step towards elaboration of general tools for climate risk assessment and evaluation of adaptation options, for use in the private sector.

The first three studies analyzed Khimti 1 hydropower facility in Nepal, Packages Bulleh Shah paper mills in Pakistan, and Ghana Oil Palm Development Company (GOPDC). This report aims to provide an overview of the approaches used in the studies and the challenges encountered. It also provides tables which summarize the main results of the studies. Full reports providing more detailed data and analyses are available at www.ifc.org/climatechange.

The lessons learned from the pilot studies included:

- The most significant climate risks on the timescales of relevance to clients are where existing climatic vulnerabilities may be exacerbated

The pilot studies



Khimti 1 power house and complex

Himal Power Ltd. Khimti 1 hydropower scheme, Nepal

Khimti 1 is a 60 MW run-of-river hydropower facility, generating 350 GWh of electricity per year, located in Dolakha District, about 100 km east of Kathmandu. The facility utilizes a drop from 1,270 to 586 m above sea level from the Khimti River, a tributary of the Tama Koshi River. Khimti 1 was built and is owned and operated by Himal Power Ltd. (HPL) and, as a public-private partnership project, will be transferred to the Nepalese government in the future. The timescale for this study was from the present day to the 2050s.

Winding reels at BSPM

Packages Ltd. Bulleh Shah Paper Mills, Pakistan

Packages Ltd. is Pakistan's premier pulp and paper packaging company and has been an IFC client since 1964. The company produces paper and paperboard, writing and printing paper, tissue products, and flexible packaging products. It uses wheat straw, recycled and waste paper, and imported pulp in its production lines. The newly established Bulleh Shah Paper Mills (BSPM), near Kasur, have allowed the company to relocate existing pulp and paper production facilities from its headquarters in Lahore to larger premises, enabling it to increase its production capacity from 100,000 to 300,000 tons per year. It also generates power on-site and sells excess power to the grid. The timescale for this assessment was from the present day to the 2040s.

GOPDC plantation worker

Ghana Oil Palm Development Company Ltd. (GOPDC), Ghana

GOPDC is an integrated agro-industrial company with two oil palm plantations, at Kwae and Okumaning in Ghana's eastern region. GOPDC also operates a mill at Kwae, where oil palm fresh fruit bunches are processed into crude palm oil (CPO) and palm kernel oil (PKO). Also at Kwae, a refinery and fractionation plant processes up to 150 metric tons/day of CPO into olein and stearin products. The timescale for this assessment was from the present day to the 2030s.

and critical performance or compliance thresholds may be crossed, as well as where systems are highly sensitive to changes in climatic factors.

- With the rapid evolution of climate science, information on changes in the frequency and intensity of extreme climatic events (e.g., heavy rainfall or major flooding), and potential impacts and consequences for a business' operations will become available.
- Using downscaled projections of global climate models for regions where these models are in good agreement can help provide better understanding of changes at a local level.
- Publicly funded research can help to develop understanding of the relationships between climatic factors and their impacts on different systems and can build generic system models. Provided that such models are made accessible, private-sector stakeholders can adapt them to better represent the specific conditions for their investments.

TABLE 1: RISK AREAS ANALYZED FOR THE THREE PILOT STUDIES

HPL Khimti 1 hydropower scheme	Packages Ltd. Bulleh Shah Paper Mill	GOPDC Ltd.
Power generation from hydropower scheme during dry and wet seasons	Wheat yields	Oil palm yield
Extreme flood event on Khimti Khola and Tami Koshi rivers	Power production from steam turbine and boiler	Oil palm pests and diseases
Landslide blocking Khimti Khola River and access road to site	Groundwater resources	Ecosystem services
Glacial lake outburst flood	Wastewater treatment plant	Refinery/fractionation plant
Increase in irrigation demand for agriculture	Pulp and paper industry generally	Power production
Local community livelihoods	Community and social issues	Groundwater resources
		Wastewater treatment
		Malaria affecting GOPDC workforce
		Community and social issues

Methodology

The studies used a risk-based approach, presented in Annex 1. The principal areas of risk identified during the process are listed in the table above.

It is worth noting that the information about climate change and its impacts applied in the studies was the best publicly available information at a specific point in time (2008/9), and that some of the pilot study findings reflect the underlying uncertainties in this evidence base. However, the ongoing and rapid advancement of climate science – new research and new generations of climate models – is expected, in time, to provide increasing levels of confidence about climate change and its impacts, even in regions currently known for difficulties in climate modeling.

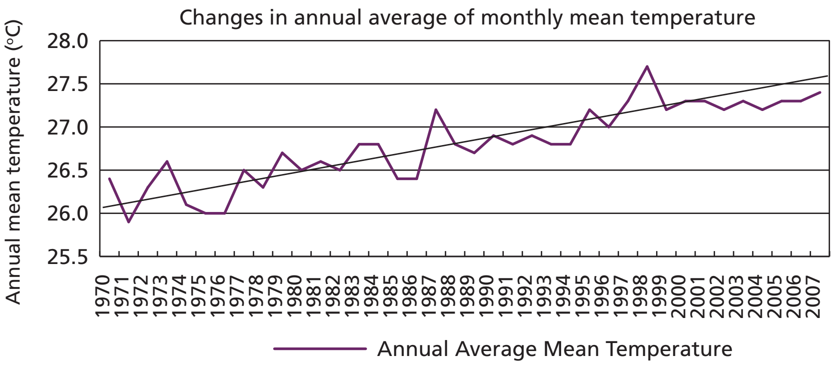
Approach to the assessments

CLIMATE DATA

Observed conditions

The studies required data on observed and future climatic conditions. Observed data were obtained from a variety of sources, including the client companies, national meteorological agencies, and the Intergovernmental Panel on Climate Change Data Distribution Centre (IPCC DDC).[1] These data were analyzed to provide a view of "baseline" climatic conditions against which future climate change impacts could be assessed and to identify any trends in the observed records. By way of example, Figure 1 shows the observed trend in annual average temperatures recorded at Akim Oda meteorological station, near GOPDC's plantations. The data show an upward trend, with an increase of 1.5°C having occurred over the period 1970–2007. This represents an increase of approximately 0.04°C per year and is an indication that the effects of climate change may already be underway in the region.

Figure 1: Trend in Observed Annual Average of Monthly Mean Temperature (°C) at Akim Oda Meteorological Station, Near GOPDC Plantations, 1970–2007



Scenarios of future climate change

Scenarios of changes in future climatic conditions were sourced mainly from the United Nations Development Program (UNDP) Climate Change Country Profiles (McSweeney, New, and Lizcano 2008). These profiles were developed to address the climate change information gap in developing countries. They provide multi-model projections of changes in future climatic conditions from 15 of the most up-to-date general circulation models (GCMs), as used in the IPCC's Fourth Assessment Report, for a range of different emissions scenarios (namely A2, A1B, and B1).[2]

The country profiles provide analyses of changes in the following climatic parameters, year by year, out to 2100, on an annual and seasonal basis:

- Mean temperature
- Mean precipitation
- Indices of extreme daily temperatures (from the 2060s onward), including the frequency of "hot" and "cold" days and nights
- Indices of extreme daily precipitation (from the 2060s onward), including the proportion of total rainfall falling in "heavy" events, maximum 1-day rainfall amounts, and maximum 5-day rainfall amounts.

---

1. Online at http://www.ipcc-data.org/ddc_visualisation.html.
2. For further information on the IPCC emissions scenarios, see the IPCC Fourth Assessment Report, available online at http://www.ipcc.ch.

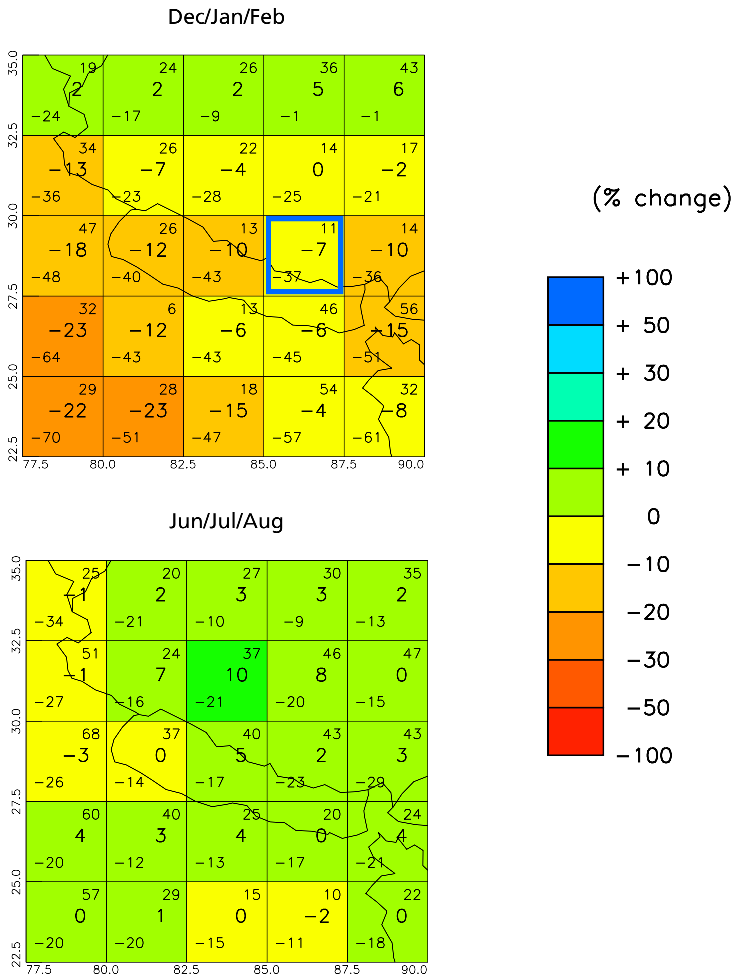
As an example, Figure 2 shows projected changes in monthly average precipitation in Nepal by the 2030s according to the country's UNDP climate change profile, using the A2 emissions scenario.[3]

On the timescales of relevance to the pilot study clients, no data were available from the UNDP country profiles on changes in the indices of extreme daily temperatures and precipitation. The limitations of applying GCMs to assessments at the scale of individual project sites are discussed below.

CLIMATE RISKS TO INVESTMENT PERFORMANCE

The data on future climate change were used to assess risks to the performance of the pilot study projects. Undertaking these risk assessments required understanding of the relationships between climatic factors and the aspect of performance (i.e., the system) being considered.

Figure 2: Projected Percentage Changes in Monthly Average Precipitation in Nepal for the Dry Season (Dec/Jan/Feb) and the Wet Season (Jun/Jul/Aug) by the 2030s, relative to the 1970–99 baseline



Source: McSweeney et al. 2008

---

[3] The grids in the figure divide the area of Nepal by longitude (x-axis) and latitude (y-axis). Khimti 1 is located in the grid box highlighted in blue in the top figure. In each grid box, the central value (large number) shows the median of the 15 climate models, and the values in the upper and lower corners are the maximum and minimum model values. According to this analysis, the median change in monthly average precipitation projected for Khimti 1 is –7 percent (low to high range of –37 to +11 percent) for the dry season and +2 percent (low to high range of –23 to +43 percent) for the wet season.

Where possible, these relationships were established based on data recorded at, or close to, the pilot study site. For example, Figure 3 uses data collected from St. Dominic's Hospital, the nearest hospital to GOPDC, to show the correlation between number of rainy days and percentage of malaria cases. Malaria poses a health risk to members of the local community, including GOPDC employees and outgrowers who supply GOPDC with their oil palm crops. The effects of the disease already impact the company's productivity.

Where no site-specific data were available, information from the scientific or engineering literature was utilized instead. For example, Figure 4 shows an analysis of the effects of temperature change on wheat yields for different latitudes, from the IPCC Fourth Assessment Report. The orange trend lines and data points on each graph show the impacts if no adaptation actions are taken in response to temperature changes, while the green lines and points show the impacts if adaptation does occur.

Figure 3: Correlation between Malaria Cases per Month (%) and Number of Rainy Days (Two Months Lagged), 2004–7, from St. Dominic's Hospital

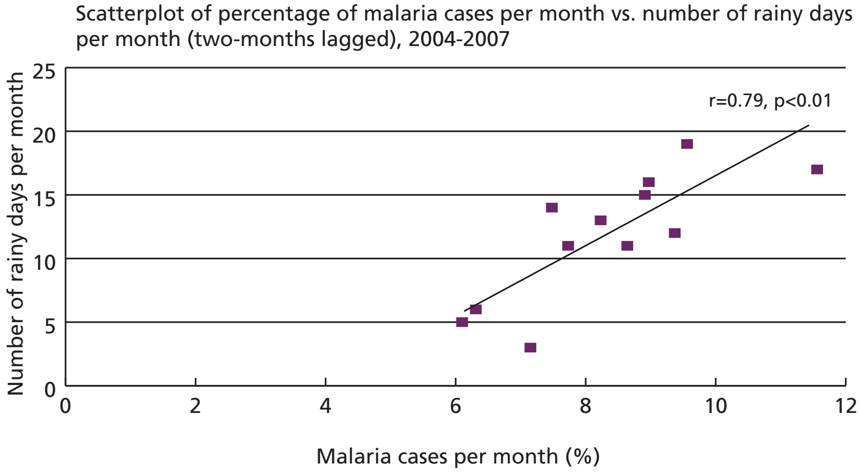
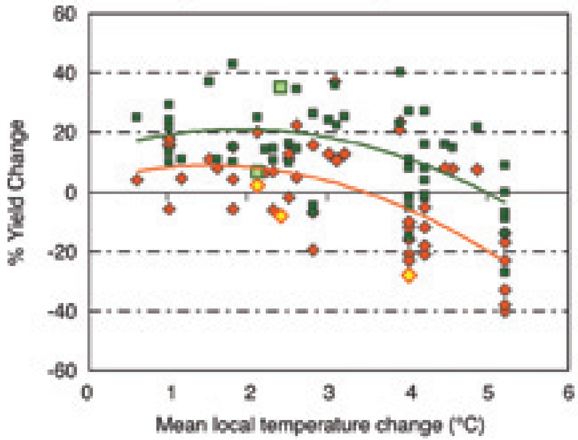
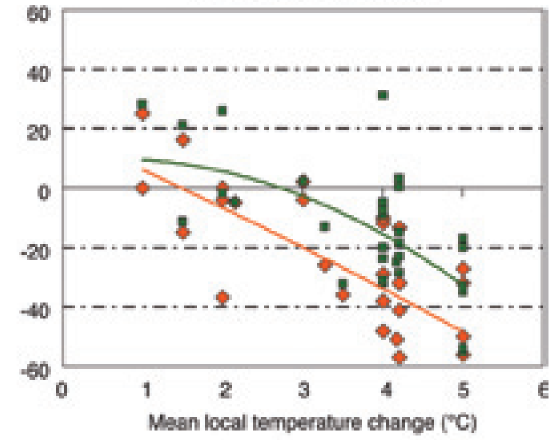


Figure 4: Sensitivity of Wheat Yield to Mean Temperature Change, Without Adaptation (orange dots) and With Adaptation (green dots)

(c) Wheat, mid- to high-latitude



(d) Wheat, low latitude



Source: IPCC 2007c, (part of) Figure 5.2

Finally, for risk areas where no literature on climate change impacts could be found, such as the industrial facilities at Packages and GOPDC, the study teams were able to work effectively with the facility managers and engineers to develop a good understanding of the risks to the companies' performance.

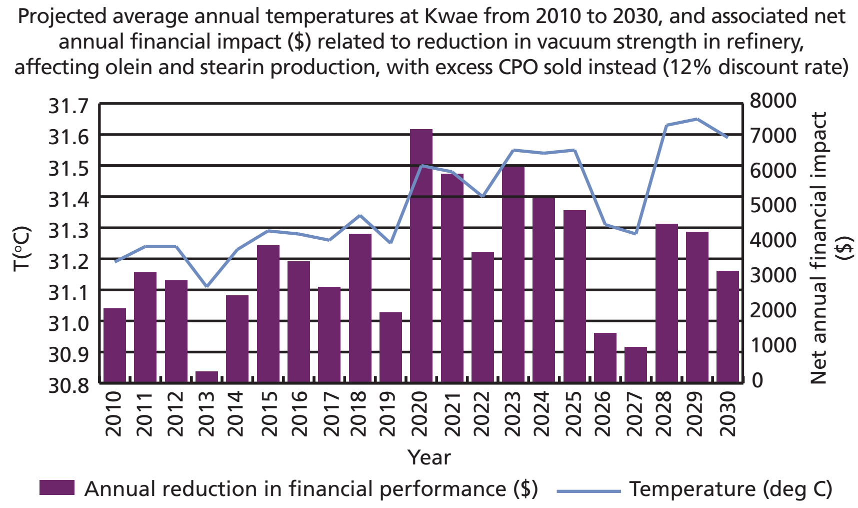
Analysis of financial impacts

Where possible, technical/operational, environmental, and social risks to client project performance were translated into financial risks. Achieving this depended on being able to apply a financial value to risks quantified in physical terms. Broadly speaking, the financial issues analyzed can be categorized as:

- changes in income due to changes in output and efficiency (see, e.g., Figure 5) or
- changes in operating costs (see, e.g., Table 2, purple text).

Some risks, such as temporary shutdowns of facilities due to extreme climatic events (e.g., major floods), clearly also have the potential to affect financial performance. However, owing to a lack of knowledge about the present-day and future probabilities of such events, it was not possible to quantify them in financial terms. Filling this gap is a research objective that is recognized by governments and scientists, and there are efforts underway to address it through various fora, such as the World Meteorological Organization and the IPCC. Still, due to the rarity of extreme climatic events and the complexities in understanding what drives changes in their incidence, this will continue to be an area of uncertainty in climate risk assessments. Strategies for robust decision making on climate resilience need to be developed despite the limitations of this imperfect knowledge.

Figure 5: Projected Net Reduction in Income at GOPDC Due to Impacts of Rising Temperatures on Refinery Vacuum Strength and Olein and Stearin Production



Note: 12% discount rate applied. Rising temperatures will negatively impact the production of olein and stearin by raising cooling water temperatures, thus decreasing vacuum strength and reducing the efficiency of GOPDC's refinery operations. These figures assume that unprocessed crude palm oil will be sold directly to market, offsetting the loss of revenue due to the reduction in olein and stearin production.

TABLE 2: PROJECTED REVENUE CHANGES FOR PACKAGES, PAKISTAN, DUE TO CHANGES IN INCOME AND FUEL COSTS RELATED TO POWER PRODUCTION

Impact	Temperature increase by 2020s		
	1.1°C	**1.26°C**	**1.88°C**
Power output of steam turbine (current level is 17.85 MW)	17.78 MW	17.77 MW	17.73 MW
Reduction in annual income due to reduced power output, based on assumed $0.1/kWhr and 340 operating days/year	–$57,000	–$65,000	–$98,000
Offset by reduction in annual operating cost of natural gas (boiler fuel)	$25,300	$28,000	$45,000
Net change in annual revenue	–$31,700	–$37,000	–$53,000
Total undiscounted change in revenue from present day to 2017	–$253,600	–$296,000	–$424,000
Total discounted change in revenue from present day to 2017 (12% discount rate)	–$157,474	–$183,803	–$263,285

Note: 2017 is the final year in Package's current financial model. Rising temperatures will produce savings for Packages in the cost of its natural gas usage by increasing boiler efficiency.

ADAPTATION ACTIONS

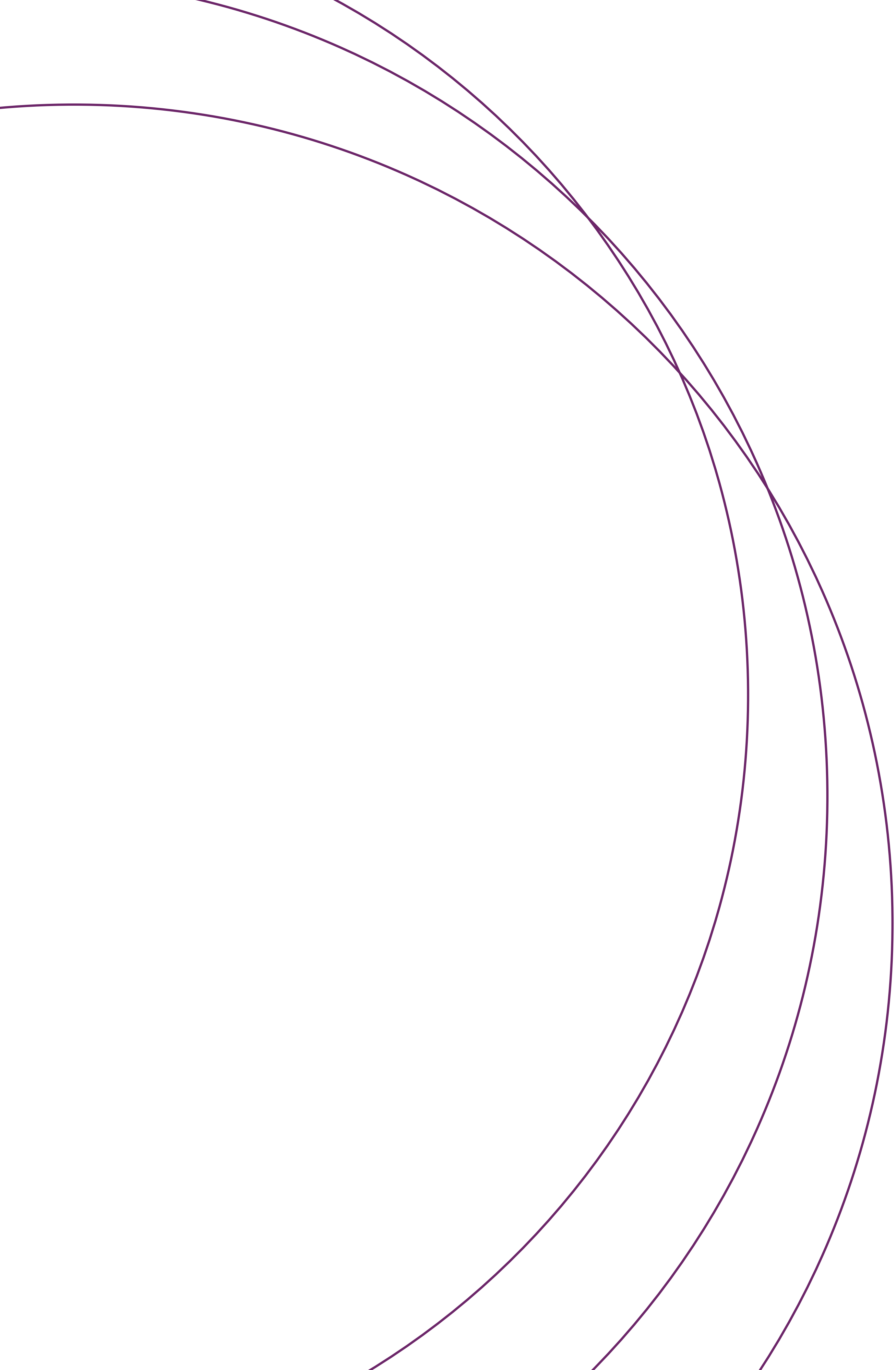
The pilot studies made less progress in analyzing the costs and benefits of adaptation actions to manage the risks identified. This is because the appropriate adaptation actions and associated costs for a given client are highly specific to the assets or processes being adapted, and decisions on when it would be appropriate to undertake action may depend on current and future regulatory positions, age, condition, and operating regimes of existing assets, as well as the client's investment plans.

> The appropriate adaptation actions and associated costs for a given client are highly specific to the assets or processes being adapted.

Instead, based on the levels of confidence in the various risk analyses, different risk management options were recommended for the clients to consider. In essence, where there was high confidence in the risk analyses, it was recommended that clients investigate the costs and benefits of adaptation actions. Where there was lower confidence associated with the risk assessments, a more exploratory approach was suggested, including research, monitoring, field trials and surveillance.

For some risk areas (such as malaria incidence affecting workers at GOPDC), the analysis showed that the effects of present-day climate variability on income were already important. In these cases, it was recommended that the client should investigate actions that could be taken now to better manage climate-related impacts.

Overall, the pilot studies have provided information on climate risks and recommendations on adaptation actions which the clients can incorporate into their mid- and long-term financial and operational plans.



Lessons learned, uncertainties, gaps and barriers

In developing the pilot studies, many issues were encountered that are common to all climate risk and adaptation assessments and which will be familiar to those who have been involved in such studies. However, there are also some aspects that are unique to undertaking these assessments with the private sector.

VALUE OF VISIT TO CLIENT SITE AND STAKEHOLDER ENGAGEMENT

The three pilot studies were undertaken in sequence; Khimti 1 was the first, followed by Packages and then GOPDC. Each study gained from the experiences of earlier studies, and the GOPDC study was able to achieve the most. Owing to security concerns in Pakistan, the visit to Packages could not be undertaken, and interaction between the client and the consultants was restricted to telephone conferences and e-mail exchanges. It became very apparent that this made a considerable difference to the depth of analysis that could be achieved for Packages compared to Khimti 1 and GOPDC. In many cases, the Packages pilot study was therefore based on generic published information in the scientific and engineering literature rather than on client-specific information.

The Khimti 1 and GOPDC visits lasted for one and two weeks, respectively. Each involved a workshop and in-depth meetings with client staff responsible for managing financial, technical/operational, environmental, and social performance, as well as site visits. These were vital in providing insights into existing climatic vulnerabilities, sensitivities, and critical climate-related thresholds. The clients were also able to provide data and reports which were used to develop the climate risk assessments.

Meetings with external parties as part of the visits, including national and local government officials, research institutes, universities, community groups and public-service providers, were also very informative. These provided data and reports on the pilot study sectors and their vulnerability to current climate conditions, as well as information on in-country research on climate change and its impacts.

The clients also noted that they benefited from the experience of being involved in the pilot studies and that it led to some changes in their activities. For instance, for GOPDC the work was a stimulus for them to begin to monitor climatically sensitive issues, to correlate some aspects of performance against climatic factors, and to engage with other stakeholders who held information about risks.

> The clients also found the interaction with the study teams to be a fruitful experience, which helped to build their appreciation of climate risk and its relevance to their objectives.

CLIMATE DATA

The climate data constraints encountered in the pilot studies are common to all climate risk assessments. They relate to uncertainties in data quality for both observed and future climate conditions.

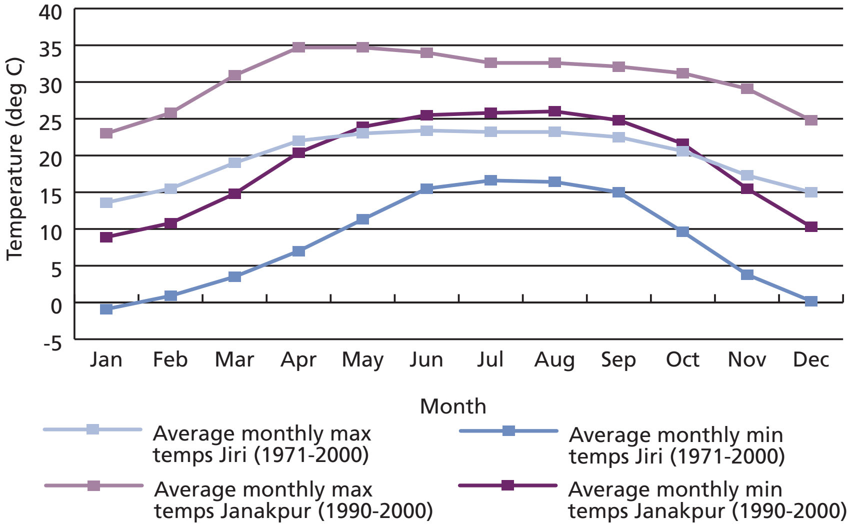
Observed conditions

Ideally, robust climate risk assessments should be undertaken by drawing on long-term (at least 30-year), high-quality records of all relevant climate statistics, measured at the project site. In practice, such data sets are seldom available, and it is often necessary to utilize data collected at meteorological stations operated by national meteorological agencies, which may not be representative of the project site.

This is exemplified in the Khimti 1 pilot study. Observed monthly temperature data for the two closest meteorological stations to the project site, Jiri and Janakpur, are shown in Figure 6. Jiri and Janakpur are both approximately 20 km (north and south, respectively) from Khimti 1 power station, at altitudes of about 2,000 m and 78 m. The Khimti 1 power station is at an altitude of approximately 700 m. As can be seen in Figure 6, the differences in altitude result in considerable differences in the climate data recorded at each meteorological station. The catchment area for the Khimti Khola River (on which the hydropower scheme relies) is in very mountainous terrain, over which there is great variation in climate conditions. To undertake a climate risk assessment of future changes in river flow, it is first necessary to develop a model that relates observed climatic conditions and observed river flows. Building such a model in an area where the baseline climate is highly spatially variable over a small area is challenging.

> Ideally, robust climate risk assessments should be undertaken by drawing on long-term (at least 30-year), high-quality records of all relevant climate statistics, measured at the project site. In practice, such data sets are seldom available.

Figure 6: Average Monthly Maximum and Minimum Air Temperatures (°C) for Jiri and Janakpur Meteorological Stations, 1971–2000



Furthermore, in order to undertake a climate risk assessment it is important to understand the natural variability in climate conditions onto which climate change effects will be superimposed. For instance, where climate change leads to decreases in precipitation, these decreases would be exacerbated in a dry year in the future, leading to potentially severe impacts, whereas they might be counteracted in a wetter year. In general, precipitation is highly variable from year to year (see, e.g., the data from Lahore, Pakistan, in Figure 7), whereas variability in temperature tends to be lower. In practice, however, given constraints on the resources available for the pilot studies, the climate risk assessments were generally performed by superimposing future climate change scenarios onto the average baseline climate conditions.

Scenarios of future climate change

The IPCC Fourth Assessment Report makes it clear that man-made climate change has been underway for decades and will continue for decades to come:

"The understanding of anthropogenic warming and cooling influences on climate has improved since the TAR [Third Assessment Report], leading to very high confidence that the global average net effect of human activities since 1750 has been one of warming (IPCC 2007b, "Technical Summary," sec. 2.5)."

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (IPCC 2007a, sec. 1.1)."

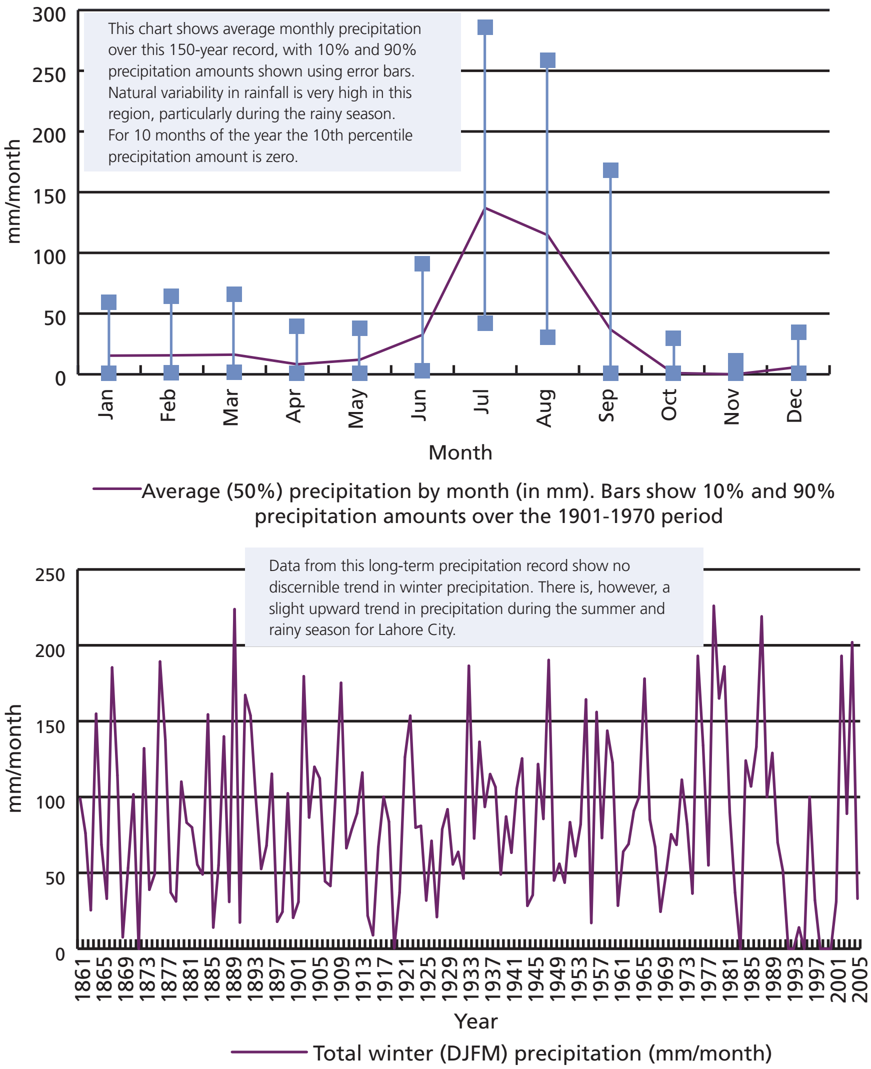
For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES[4] emission scenarios.

"Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised (IPCC 2007a, sec. 3)."

---

[4] Special Report on Emissions Scenarios; IPCC 2007a, "Summary for Policymakers"

Figure 7: Observed Monthly Precipitation at Lahore (top) and Time-Series of Winter (Dec/Jan/Feb/Mar) Precipitation at Lahore (bottom), 1861–2008



This chart shows average monthly precipitation over this 150-year record, with 10% and 90% precipitation amounts shown using error bars. Natural variability in rainfall is very high in this region, particularly during the rainy season. For 10 months of the year the 10th percentile precipitation amount is zero.

Data from this long-term precipitation record show no discernible trend in winter precipitation. There is, however, a slight upward trend in precipitation during the summer and rainy season for Lahore City.

Source: KNMI (Royal Netherlands Meteorological Institute), available online at http://climexp.knmi.nl

There is high confidence that the climate in the coming decades will change rapidly and will not be like the relative stable climate of the recent past. In particular, projected temperature changes are well characterized, and agreement between the different climate models is generally good. Additionally, changes in future emissions of greenhouse and other gases that affect the climate can be understood with relatively high confidence on the timescales of relevance to the private sector by using a range of emissions scenarios in risk assessments.

Nevertheless, in any given location, there are uncertainties about precisely what future climate conditions will be experienced, and approaches have been developed by climate scientists to characterize these, as have approaches to robust decision making in the face of these uncertainties. The key dimensions of uncertainty are outlined below, along with discussion of how each dimension could be better understood.

How global climate change will translate at the local level. To some extent, this can be analyzed by investigating risks based on a wide range of global (coarse-scale) and regional (finer-scale) climate models and/or using statistical downscaling techniques. At present, there are many global climate models to draw from, but far fewer regional models. Furthermore, in some parts of the world the global climate models are not good at simulating baseline climate conditions, nor are they in agreement about projections of future changes, particularly in relation to precipitation (see Figure 2 above for an example). These kinds of model uncertainties are not untypical, particularly in areas where the topography is complex (highly mountainous regions or coastal areas) and in regions with monsoon or tropical climates. According to the IPCC's Fourth Assessment Report:

> "There are substantial inter-model differences in representing monsoon processes, and a lack of clarity over changes in ENSO [El Niño Southern Oscillation] further contributes to uncertainty about future regional monsoon and tropical cyclone behaviour. Consequently, quantitative estimates of projected precipitation change are difficult to obtain" (IPCC 2007b, sec. 11.4).

Coarse spatial resolution of climate models. Because of the coarse spatial resolution (typically 2.5° x 2.5°) of the grid used in GCMs, they provide "smoothed" estimates of future changes. However, if the topography within an individual 2.5° x 2.5° grid square is highly variable (as is the case for the location of Khimti 1), then the local changes may be higher or lower than the smoothed estimates. The recommended approaches to tackling this are to generate downscaled projections using regional climate models or statistical downscaling tools, driven by multiple GCMs. However, in areas where the global climate models are not in agreement, there is little to be gained by undertaking downscaling. This was deemed to be the case for all three pilot studies.

Changes in climatic extremes and timescales of projections. To evaluate the full range of risks posed by climate change to an investment, it is important to consider changes in both long-term average and extreme climatic conditions. However, in general, there is very little information available on changes in extremes (e.g., 1-in-100-year storm-surge height, maximum hourly rainfall intensity), and what is available is often only for the end of the 21st century. There are various reasons for this information gap, including a lack of data on observed extreme events (by nature of their rarity), which constrains the ability of climatologists to understand how they may change in the future, as well as limitations in the amount of climate model data that are stored by meteorological offices around the world. It is clear that additional investment in research by public-sector organizations could be usefully targeted to addressing this important gap.

ASSESSMENTS OF RISK TO INVESTMENT PERFORMANCE

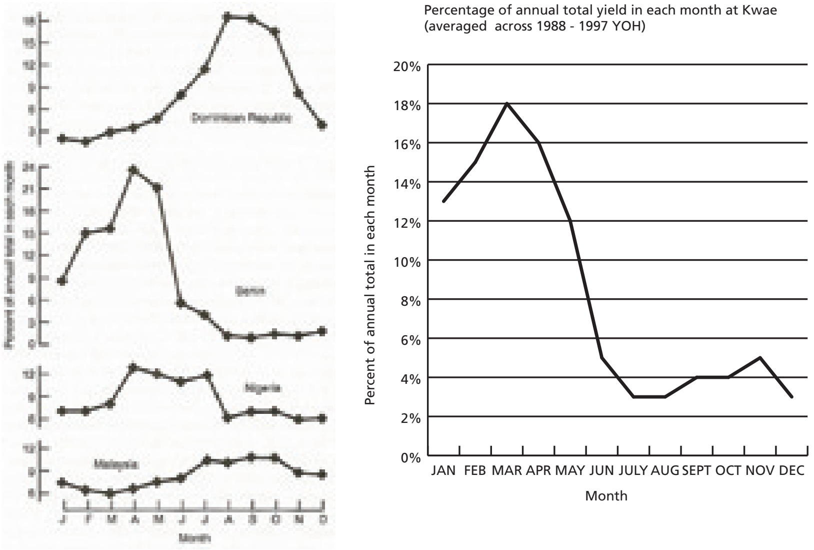
As noted, evaluating climate change risks to the performance of the pilot study projects required understanding the relationships between climatic factors and the aspects of performance being considered. In most cases for the pilot studies, this required knowledge which was not already available. Where possible, within the resource and data constraints of the pilot studies, statistical models were constructed to represent these relationships. However, the development of system models is often fraught with complexity, and uncertainties about system response to climatic and nonclimatic factors constrain the robustness of these assessments. There are two stakeholder groups who can help to address these constraints. First, publicly funded research can help to develop understanding of the relationships between climatic factors and their impacts on different systems and can build generic system models. Second, provided that such models are made accessible, private-sector stakeholders can adapt them to better represent the specific conditions for their investments.

To appreciate this complexity, consider the analyses of the relationships between oil palm yield at GOPDC and the climatic and nonclimatic factors which influence it. In general, oil palm yield is affected by a range of nonclimatic factors, including palm age, soil type, seed type and management practices. Yield is also affected by the abundance of oil palm pollinators and outbreaks of pests and diseases, both of which can be influenced by climate. Disentangling these influences is a major research undertaking, and it appears that no model currently exists which captures all these factors.

Furthermore, large seasonal variations in oil palm yield are expected in regions such as West Africa, where severe dry periods are common. However, researchers have reported that similar, though less extreme, seasonal variations are also evident in regions with more uniform climates, such as Malaysia. This annual cycling is reported to have a large influence on yield even in regions that lack marked seasonal variations in climatic factors, and it also persists in irrigated conditions. Figure 8 compares the seasonal yield cycles in four oil-palm-producing countries to that at GOPDC, demonstrating that in addition to seasonal variability within each country, there is also significant variation in the yield cycle across countries. This means that in order to fully understand the range of factors affecting oil palm yield in any given location, a specific model must be developed for that country.

Complexity is further compounded by the numerous stages in the development of oil palm fruits (from which crude palm oil is extracted), each of which is differently vulnerable to climatic conditions. Table 3 summarizes the stages which determine the final inflorescence and bunch characteristics of oil palm, as reported in different studies. It is clear that there is much variation in the lengths of oil palm development stages reported in the literature, so attempts to correlate observed climate data to oil palm yields are difficult to undertake.

Figure 8: Seasonal Yield Cycles in Different Countries Compared to Seasonal Yields at GOPDC, Kwae Plantations, for 1988–97 Years of Harvest



Source: Adapted from Corley and Tinker 2003

ANALYSIS AND RECOMMENDATIONS ON ADAPTATION ACTIONS

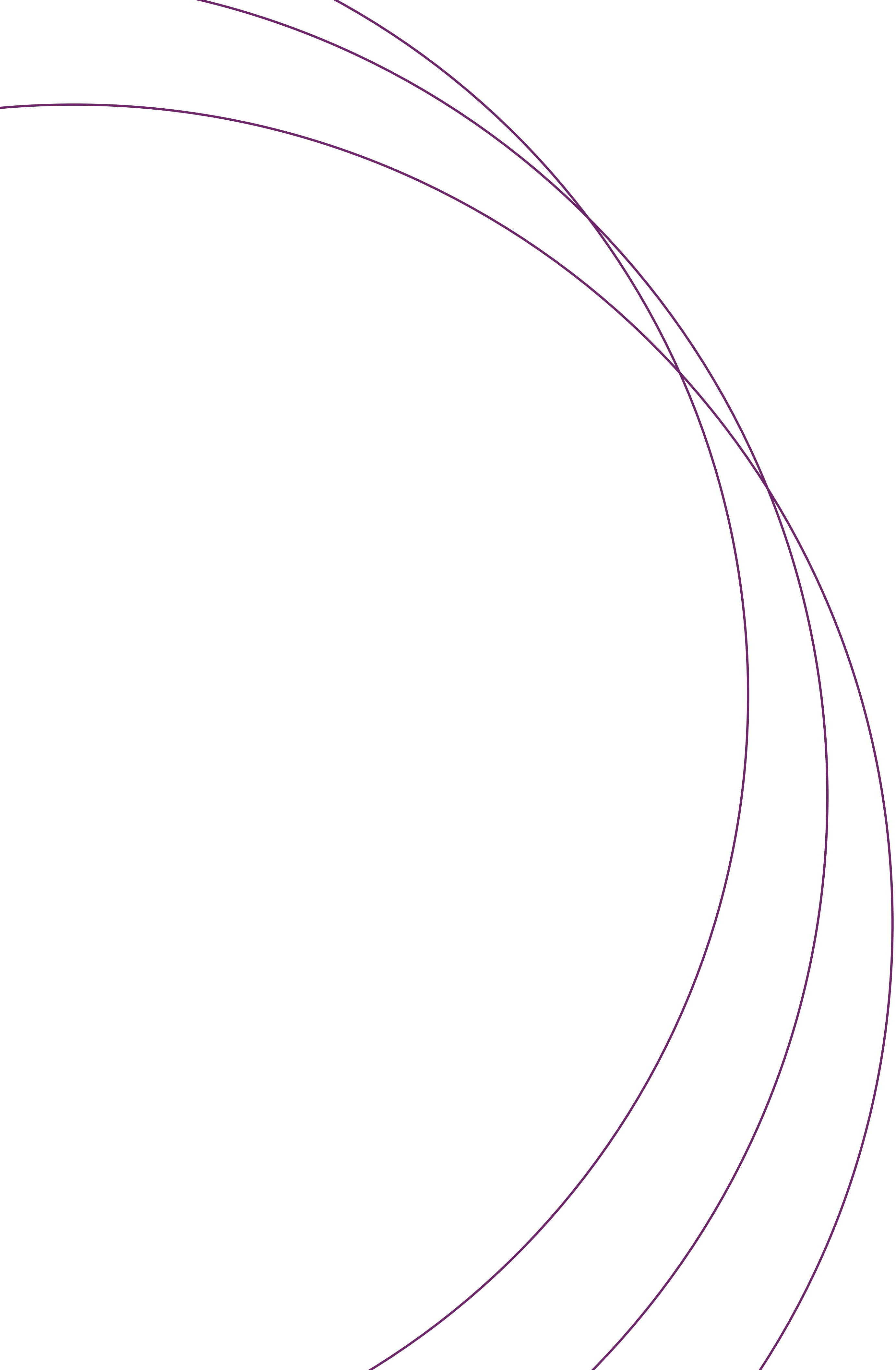
As is clear from the preceding discussion, undertaking robust risk assessments for the pilot studies was a complex process, and future improvements will require investment in research at all steps in the risk assessment chain. Until these uncertainties are better resolved, it can be difficult to justify expenditure on physical adaptation actions to clients. For instance, design standards for assets aimed at preventing pollution from facilities are often based on extreme events (e.g., site drainage systems and mine tailings dams are designed based on anticipated extreme precipitation amounts), but until there is better understanding of how the intensity or frequency of such events will change in the future, it would not be sensible to propose that a client upgrade existing infrastructure. There are, however, often opportunities to build in resilience against future climate changes at lower cost when designing new facilities.

TABLE 3: DEVELOPMENT STAGES OF OIL PALM FRUIT COMPONENTS, ACCORDING TO VARIOUS STUDIES

	Approximate months before harvest		
Development stage	**Breure and Menendez 1990, Malaysia**	**Oboh and Fakorede 1990, Nigeria**	**Corley and Tinker 2003, various studies/locations**
Inflorescence initiation	38	—	44 (Ivory Coast). Corley also found a range of 26–37 months for different clones.
Sex determination	18	30	21–29
Inflorescence abortion	11	11	9–10
Flowers per spikelet	19	—	12–15
Spikelet number	24	17–24	Within 9 months
Frame weight (stalk plus spikelet)	7–9	—	No clear response
Anthesis and fruit set	6	—	5

For some of the systems evaluated in the pilot studies, the study teams were able to work with the client to develop a sound understanding of the risks, which provided a good basis for decision making on adaptation. The strongest examples of this relate to risks associated with increases in average temperatures, which affect power production at Packages and refinery output at GOPDC (as shown in Table 2 and Figure 5 above).

> Undertaking robust risk assessments for the pilot studies was a complex process, and future improvements will require investment in research at all steps in the risk assessment chain.



General results and conclusions

MOST SIGNIFICANT RISKS AND UNCERTAINTIES

In general, on the timescales of relevance to private sector investments, changes in monthly, seasonal, or annual average climate conditions are small (on the order of 1°C–2°C temperature increases and +/– 5 to 10 percent changes in precipitation). As a result, the pilot study analyses indicate that the most significant risks on these timescales are where:

- Existing climatic vulnerabilities may be exacerbated and critical thresholds crossed.
  For instance, for the Khimti 1 hydropower scheme, HPL is under an obligation to maintain dry-weather flows in the Khimti Khola River above certain levels downstream of the Khimti 1 intake. If climate change were to lead to greater incidence of low flows, then the requirement to meet this critical threshold could affect the power produced at Khimti 1. In actual fact, the modeling undertaken in the Khimti 1 pilot study did not indicate that the risk of flows falling below this threshold would be exacerbated in the future.
- Systems are highly sensitive to changes in climatic factors.
  For instance, GOPDC's refinery and fractionation plants are sensitive to small increases in cooling water temperature, which reduce the effectiveness of vacuum-producing systems and extend crystallization times. Hence, production rates of olein and stearin are reduced. Variations in temperature from day to night already have significant impacts on crude palm oil throughput at the refinery when cooling water temperatures exceed the design threshold of 32°C. Throughput can be 20 percent lower in the daytime, when it is hotter. In future, the vacuum systems are expected to become less effective as temperatures rise (see Figure 5 earlier), and crystallization times will extend, leading to a reduction in olein and stearin output. An extra cooling tower has recently been installed at GOPDC to serve the refinery. This will help to reduce the impact of rising temperatures on refinery output, though it will not completely eliminate it.

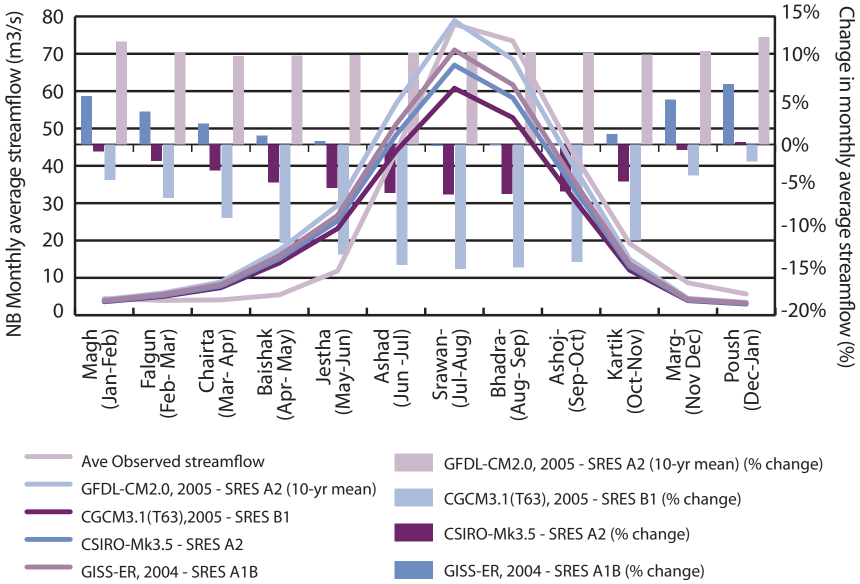
Water resources are a key concern

A feature of all the pilot studies (in common with the majority of private sector investments) is their reliance on water resources.

Khimti 1 hydropower scheme river flows. For Khimti 1, clearly, the output of the hydropower scheme is dependent on flows in the Khimti Khola River. Owing to uncertainties about future changes in rainfall and about modeling the impacts of these changes on river flows, it was not possible to determine with confidence how climate change will affect flows. The variations projected for the 2020s, using four climate models and three emissions scenarios, are shown in Figure 9. From the point of view of power production, changes in flows in the dry season are the most critical, because monsoon flows exceed Khimti 1 capacity by a large margin. In the dry months, the modeling indicates that flows could change by about +/– 10 percent by the 2020s. It should be noted that the model outputs become more consistent over time; by the 2050s there is a clearer indication of an increase in dry-season flows.

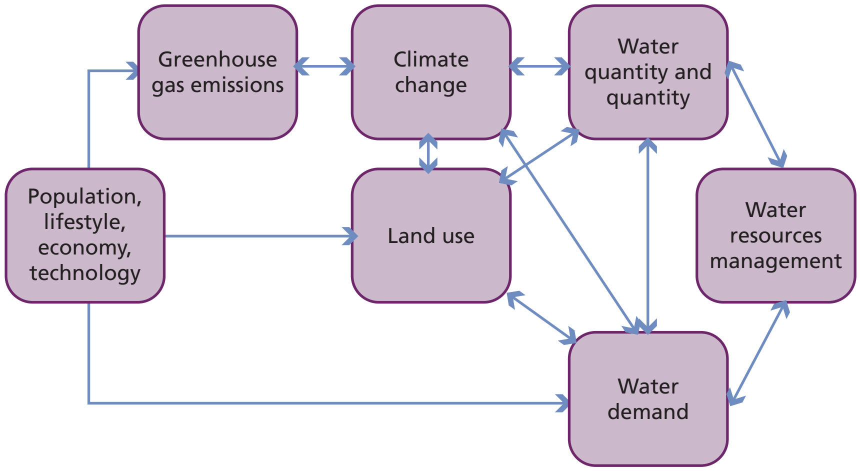
> A feature of all the pilot studies (in common with the majority of private sector investments) is their reliance on water resources.

Figure 9: Monthly Projections of Stream Flow at Rasnalu Flow Gauging Station (close to Khimti 1 intake), under Four GCMs for the 2020s, Using Empirical River Flow Models



Note: Projections are for Nepalese months, as shown on the x-axis.

Figure 10: Factors Affecting the Way Human Activities Impact Freshwater Resources



Source: Modified from Oki 2005

Groundwater at Packages and GOPDC. Both Packages and GOPDC rely on groundwater for their industrial operations (pulp and paper production at Packages, and production of crude palm oil and olein and stearin at GOPDC's mill and refinery). For Packages, growth of wheat straw, which is one of the inputs to its pulp and paper mills, also relies on groundwater irrigation, and GOPDC's oil palm nursery is irrigated using groundwater.

These dependencies mean that any changes in the availability of groundwater resources could pose significant risks to the investments. Yet the pilot studies indicate that the vulnerabilities of these resources to climatic and nonclimatic factors are not currently well understood. The complex links between climate change and other factors influencing water supply and demand are highlighted in Figure 10.

Groundwater is something of a hidden resource, by virtue of its not being visible. While both Packages and GOPDC monitor groundwater levels in boreholes, neither company has undertaken a wider assessment of the climatic and nonclimatic factors influencing the aquifers that they are using. Improved long-term monitoring could include researching the relationship between borehole water levels and climatic variables, considering time delays between climatic events and their impacts on groundwater levels. The companies could also consider commissioning surveys of the catchment areas for the aquifers they are using to better understand the factors that influence their recharge. Based on such surveys, models of the aquifers could be constructed to provide the basis for future resource management.

To evaluate risks from climate change for groundwater recharge at Packages, the pilot study used two groundwater models, driven by climate change scenarios from multiple GCMs, under three emissions scenarios. The results of this risk assessment are presented in Figure 11. As shown in the figure, the majority of the model runs indicate a future increase in groundwater recharge. Using the Amritsar groundwater model, 77 percent of the model results show an increase for the 2020s, and 67 percent do for the 2040s. Using the CATCHMOD model, about 88 percent of the model projections show an increase in both time periods. This is because nearly 75 percent of precipitation in the region falls during the monsoon season, and this is when most of the natural recharge occurs, through water being absorbed into the soil rather than evaporating. Most of the climate models project an increase in monsoon-season precipitation.

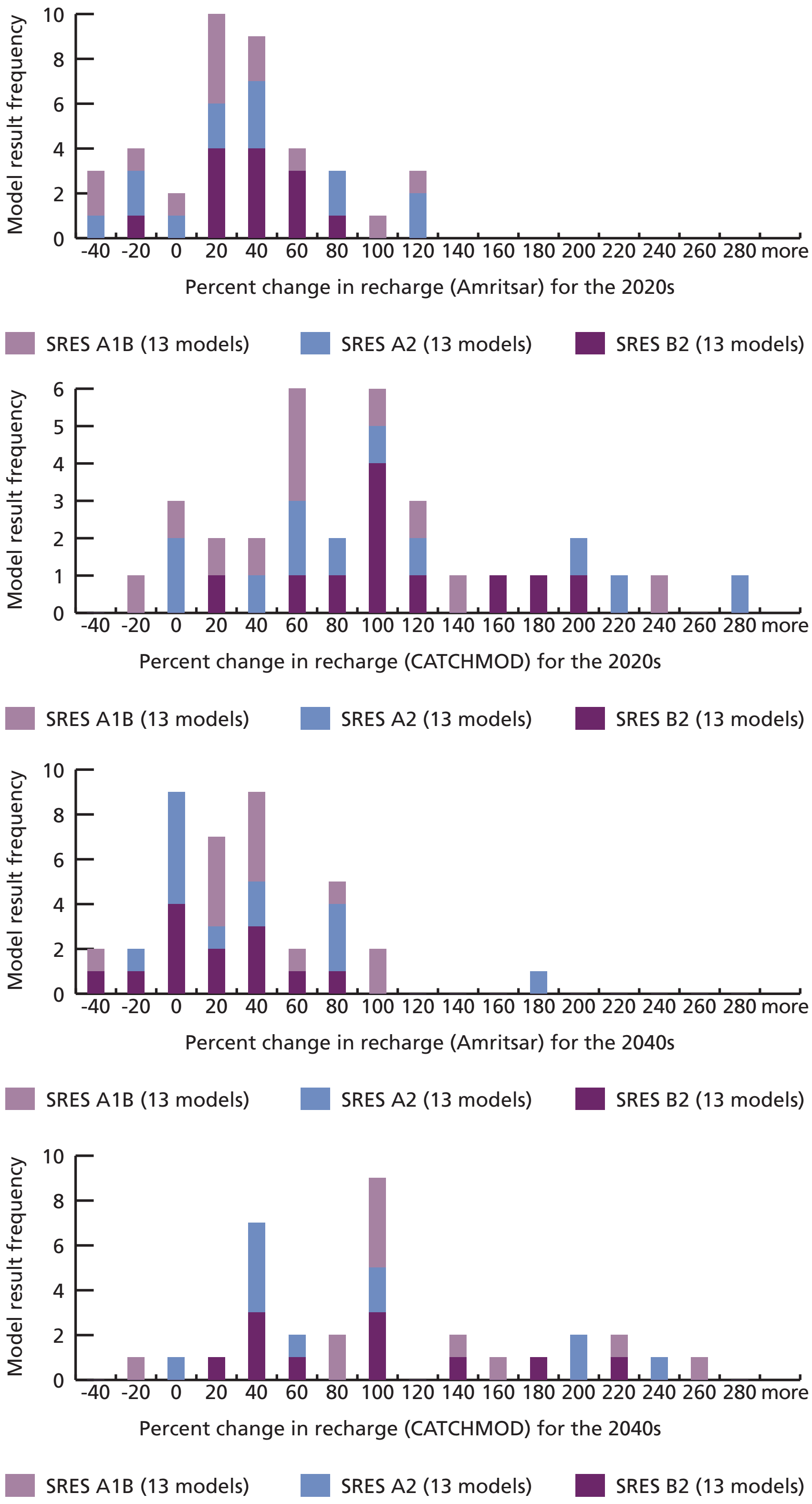
While this kind of assessment is very useful for characterizing the uncertainties in future recharge, it is important to note that to understand fully future risks, changes in groundwater demand by Packages and other users (e.g., for crop irrigation) related to climate and socioeconomic changes need to be evaluated.

Low-probability / high-consequence events

There are significant unknowns regarding future changes in the occurrence of low-probability (extreme) / high-consequence events. These could represent the highest risks to the pilot study clients, but it was not possible to evaluate their significance. The notable examples of these from the Khimti 1 and GOPDC pilot studies are highlighted in Table 4.

Further research and monitoring to help evaluate the significance of these risks, though challenging, would be very worthwhile, because when these unlikely events occur, they can have very large financial consequences. For GOPDC, a single outbreak of the leaf miner (a pest which causes widespread defoliation of oil palms) could lead to revenues not earned of $1.8 million. An outbreak occurred at GOPDC's plantation in 1987, and 13,000 tons of oil palm fresh fruit bunches (from which the palm oil is extracted) were lost. The leaf miner is known to be sensitive to temperature, rainfall and carbon dioxide concentrations, but there is little information on these sensitivities, and the impacts of climate change on leaf miner incidence have not been researched in any depth.

Figure 11: Frequency of Projected Groundwater Recharge, as Calculated Using Two Groundwater Modeling Methods



Note: Projections for the 2020s are shown in the top two figures and for the 2040s in the bottom two figures.

TEMPERATURE-RELATED IMPACTS ON INDUSTRIAL PROCESSES CAN BE WELL CHARACTERIZED

As noted above, climate models are generally in good agreement about future increases in temperature. The impacts of rising temperatures on industrial processes at GOPDC and Packages were evaluated with a higher degree of confidence than other issues, because the relationships between temperature and process performance are well understood. In general, industrial equipment that generates heat (e.g., turbines, compressors, motors) is likely to see some efficiency losses due to the higher temperatures expected under climate change.

Further research and monitoring to help evaluate the significance of these risks, though challenging, would be very worthwhile, because when these unlikely events occur, they can have very large financial consequences.

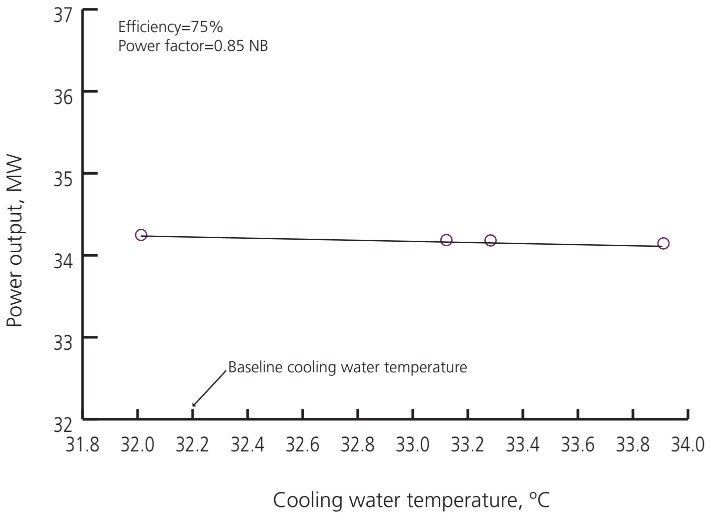
TABLE 4: LOW-PROBABILITY / HIGH-CONSEQUENCE EVENTS FOR KHIMTI 1 AND GOPDC

Khimti 1	GOPDC
Extreme flood event on Khimti Khola and Tami Koshi rivers	Oil palm pest or disease outbreak
Landslide blocking Khimti Khola River and access road to site	Loss of natural oil palm pollinator
Glacial lake outburst flood	

In the case of GOPDC, one financial impact associated with rising temperatures is the reduction in olein and stearin production (see Figure 5 above). The relationship between temperature and production rates was recorded on-site by GOPDC's refinery production manager and was established with a high degree of confidence.

Packages generates power on-site and sells surplus power to the grid. The condensing steam turbine efficiency at the power plant is slightly reduced by temperature increases, and again, the relationship is well understood (see Figure 12). This information allows a highly confident projection of a small reduction in Packages' future income from power sales (as shown above in Table 2).

Figure 12: Power Output of Packages' 41 MW Siemens Condensing Steam Turbine with Double Extraction vs. Cooling Water Temperature



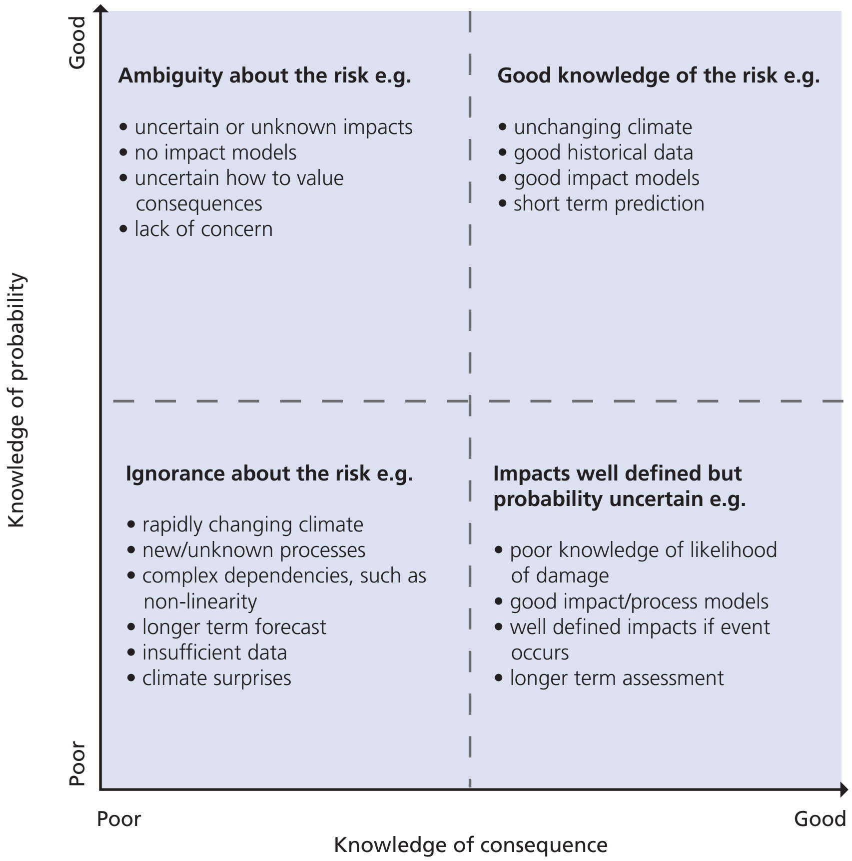
FROM UNCERTAINTY TO RISK

Risk is a function of two dimensions: the probability of a hazard and the magnitude of its consequence. The quality of knowledge of each of these dimensions is a measure of how well a risk is understood (see Figure 13).

As outlined earlier, information on future changes in extreme climatic events is scarce, and there is uncertainty in all the pilot studies locations about whether seasonal average precipitation will decrease or increase in the future—the quality of knowledge about the probability of these changing hazards is poor.

For some of the issues explored in the pilot studies, there was little evidence about how the system would be affected by changes in climate. For instance, literature is lacking on how the presence of GOPDC's natural oil palm pollinator and the leaf miner pest are correlated with climatic factors. Yet, total loss of the pollinator would have an estimated financial impact for GOPDC of more than $1 million per annum. A major leaf miner outbreak could lead to revenues not earned of $1.8 million per annum. Lack of availability of groundwater at GOPDC would lead to the mill and refinery being shut down, but the sensitivity of this resource to climate change is unknown.

Figure 13: Quality of Knowledge of Climate Change Risks to GOPDC



Ambiguity about the risk e.g.

- uncertain or unknown impacts
- no impact models
- uncertain how to value consequences
- lack of concern

Good knowledge of the risk e.g.

- unchanging climate
- good historical data
- good impact models
- short term prediction

Ignorance about the risk e.g.

- rapidly changing climate
- new/unknown processes
- complex dependencies, such as non-linearity
- longer term forecast
- insufficient data
- climate surprises

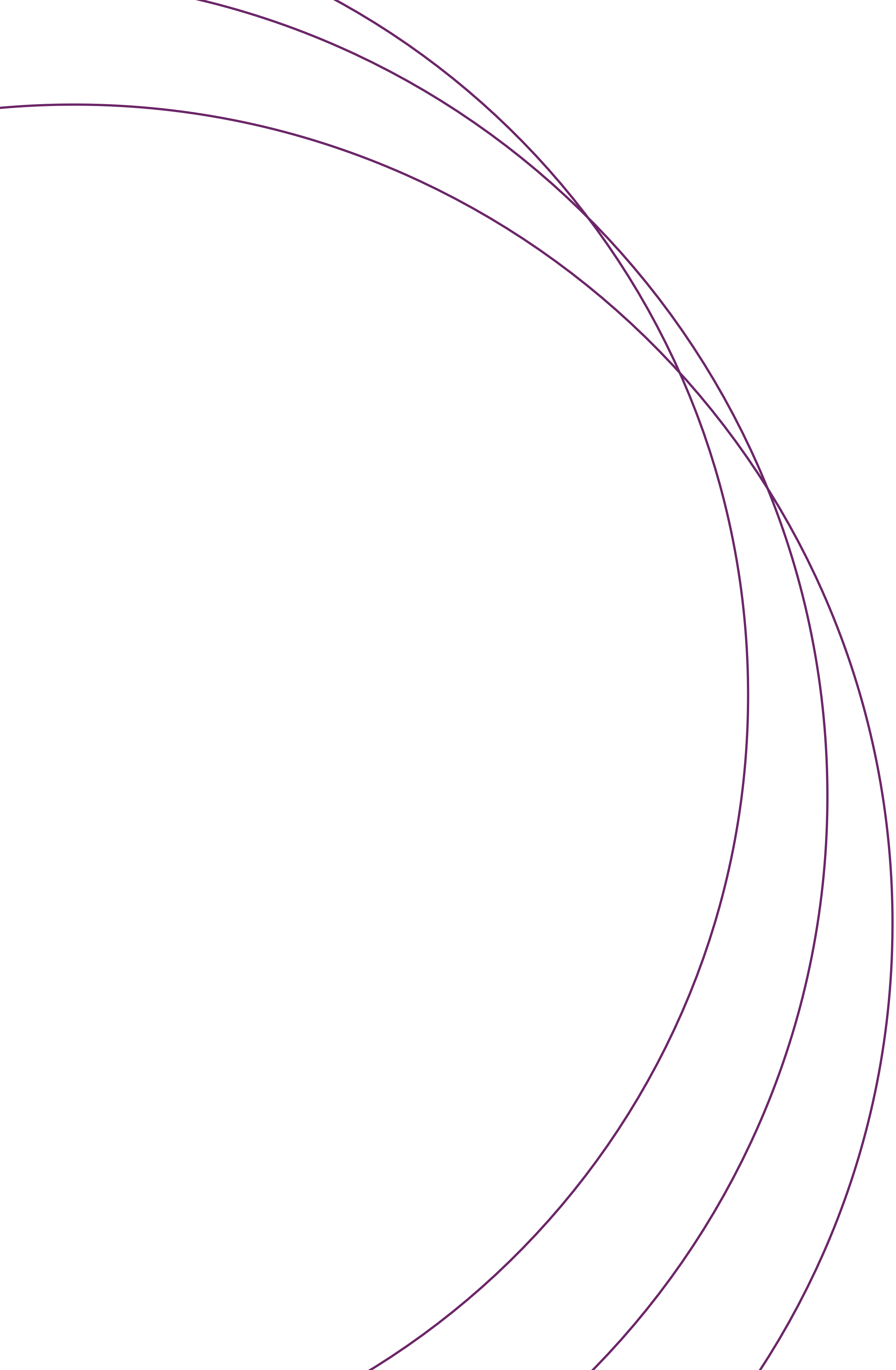
Impacts well defined but probability uncertain e.g.

- poor knowledge of likelihood of damage
- good impact/process models
- well defined impacts if event occurs
- longer term assessment

Source: Willows and Connell 2003

On the other hand, temperature-related risks to industrial operations at GOPDC could be quantified with some precision, because both the probability of the hazard and the magnitude of its consequence were known with a good degree of confidence.

The potentially significant financial consequences outlined above provide a strong signal on the areas where future efforts to reduce uncertainties should be focused, so that risks can be better understood and appropriate adaptation actions undertaken.



Annex 1: A risk-based approach

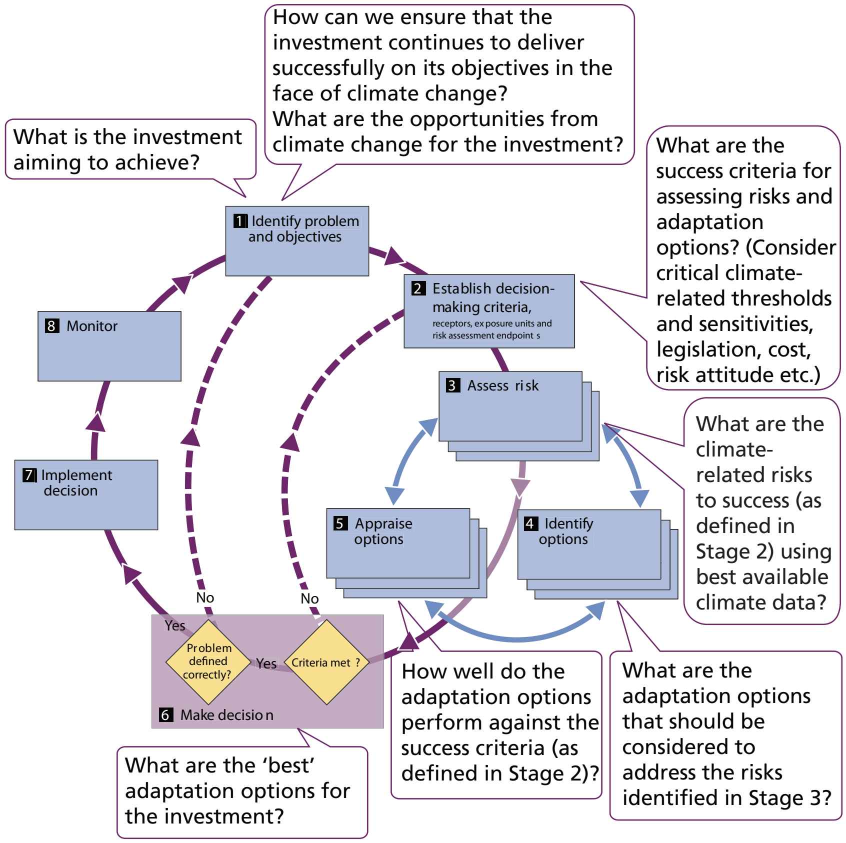
Figure 14 illustrates the risk-uncertainty decision-making framework which forms the basis of the pilot study methodology. The framework was developed by the U.K. Climate Impacts Programme (UKCIP) and the U.K. Environment Agency (Willows and Connell 2003). It sets out eight stages, of which the first six were followed in the studies. The key questions addressed at each stage of the process are shown on the figure.

Stages 5 and 6 were explored in less depth than stages 1–4, because these later stages required knowledge of the costs and benefits of adaptation options, which was not readily available.

In practical terms, the pilot studies involved:

- a visit to the project site (except in the case of Packages),
- meetings with the IFC client, to discuss climatic sensitivities and vulnerabilities, obtain data, reports, and so forth,
- meetings with in-country sector experts and climate change experts from the public sector, research institutions, universities, and community groups,
- literature reviews and qualitative analysis of impacts, and
- quantitative assessments of impacts, where possible.

Figure 14: Climate Risk Assessment and Management Framework Used in the Pilot Studies



Source: Willows and Connell 2003

The specific risk areas considered varied from study to study (see Table 1 above), but in general terms, all the studies aimed to provide a holistic approach by analyzing risks to the technical/operational, environmental, social and financial performance of the investments.

Annex 2: Summary results of pilot studies

TABLE 5: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR KHIMTI 1

Issue	Most important climate factors	Description of climate risks	Impact	Confidence in the assessment	Recommended adaptation options
Generation during dry season	Changes in precipitation	Changes in precipitation will have a direct effect on the hydrology of the Khimti Khola River. A hydrological model developed for the case study using inputs from four climate models shows significant changes in dry season flows in the Khimti Khola.	The impact on generating output is most significant during the dry weather season. However, there is little consistency between the climate models, with two showing increases in flows and two showing decreases in flows.	Low confidence in projections of changes in precipitation due to inconsistency between GCM model outputs. High confidence in the link between precipitation, flow, and generating output.	The information available at this stage is insufficient to enable HPL with any degree of certainty to make any decision on asset replacement or further capital investment. At this stage, in the early years of the current PPA and with the major assets having a significant future asset life, it is recommended that the adaptation options taken by HPL be for the most part directed at building adaptive capacity rather than delivering adaptation action. (HPL)
Generation during wet season	Changes in precipitation	Changes in precipitation will have a direct effect on the hydrology of the Khimti Khola River. A hydrological model developed for the case study using inputs from four climate models shows significant changes in wet season flows in the Khimti Khola.	Although the impact on flows is greater in the wet season, there is no impact on generating output and revenue. Khimti 1 already operates at capacity during the wet season.	Low confidence in projections of changes in precipitation due to inconsistency between GCM model outputs.	No adaptation options are recommended. (Additional capacity could, in theory, be provided by increasing the main tunnel size and adding new turbines. The costs would be prohibitive and the additional capacity would not be utilized during the dry weather season).

TABLE 5: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR KHIMTI 1

Issue	Most important climate factors	Description of climate risks	Impact	Confidence in the assessment	Recommended adaptation options
Extreme flood event on the Tama Koshi	Changes in precipitation. Changes in temperature.	Changes in precipitation and temperature (including impacts on snow and glacial melt) will have a direct effect on the hydrology of the Tama Koshi River.	Insufficient information is available to undertake a flood-risk assessment. HPL's insurance cover does provide for protection in the event of a major flood.	Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified. Low confidence in ability to calculate financial impacts, resulting from lack of baseline information.	Undertake a detailed flood-risk assessment (HPL)
Extreme flood event on the Khimti Khola	Changes in precipitation. Changes in temperature.	Changes in precipitation and temperature (including impacts on snow melt) will have a direct effect on the hydrology of the Khimti Khola River. Sediment loads would increase. The intake structure and sediment channels would be at risk.	Insufficient information is available to undertake a flood-risk assessment. HPL's insurance cover does provide for protection in the event of a major flood.	Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified. Low confidence in ability to calculate financial impacts, resulting from lack of baseline information.	Undertake a detailed flood-risk assessment (HPL)
Landslide blocking the Khimti Khola	Changes in precipitation	Changes in precipitation will have a direct effect on the landslide risks in the area. The risks are compounded by geology and the lack of vegetation and tree cover in many areas. A blockage of the river upstream of Khimti 1 would prevent electricity generation. A flood risk would also be created in the river.	Insufficient information is available to undertake a flood-risk assessment. HPL's insurance cover does provide for protection in the event of damage due to landslide and a major flood. Generating outputs and revenues would be affected for the duration of the blockage.	Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified.	HPL actively monitors landslide risks in the vicinity of its intake structure. No further adaptation measures are recommended.

TABLE 5: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR KHIMTI 1

Issue	Most important climate factors	Description of climate risks	Impact	Confidence in the assessment	Recommended adaptation options
Landslide blocking road access to Kirne	Changes in precipitation	Changes in precipitation will have a direct effect on the landslide risks in the area. The risks are compounded by geology and the lack of vegetation and tree cover in many areas. A blockage of the access road would create a temporary restriction.	There are frequent landslides in the area. HPL's site contingency plans provide for storage of essential supplies on site. The main assets can all be reached by helicopter. It is unlikely that generating outputs and revenue would be affected.	Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified.	No specific adaptation options are recommended.
Local community livelihoods	Changes in rainfall and precipitation during both the dry and wet seasons	The subsistence farming in the area creates existing vulnerabilities. Farmers report declining yields due to changes in the monsoon. Other aspects of community well-being are also vulnerable to climate, including transport, health, and water quality.	The direct financial impacts on HPL and Khimti 1 are minimal.	Low confidence in the climate models' ability to show changes in the monsoon at a regional level.	Continued support for local communities (HPL)
Glacial lake outburst flood (GLOF)	Combination of temperature and precipitation	Glacial retreat is occurring all over the Himalayas. As temperatures increase the rate of retreat is accelerating. The risks associated with the glacial retreat in the Tama Koshi catchment are well documented. Remedial works have been undertaken to the Tsho Rolpa glacial lake.	It is not known if a GLOF would affect Khimti 1. Insufficient information is available to undertake a flood-risk assessment. HPL's insurance cover does provide for protection in the event of a GLOF.	High confidence in projections of higher temperatures. Low confidence in ability to calculate financial impacts, resulting from lack of baseline information.	Reinstate early warning remote monitoring systems. (Nepal Government) Undertake a detailed flood-risk assessment. (HPL)

TABLE 5: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR KHIMTI 1

Issue	Most important climate factors	Description of climate risks	Impact	Confidence in the assessment	Recommended adaptation options
Power Purchase Agreement (PPA)	Changes in precipitation	The dry weather flows in the Khimti Khola will change.	There are underlying issues with regard to the PPA that are unrelated to the impacts of climate change. Adaptation actions will need to be considered within the context of these underlying issues and their resolution.	High confidence in the link between precipitation, flow, and generating output.	The analysis using some of the climate models points to changes in flows.
Increase in irrigation demand. Pressure to increase minimum flow at Khimti 1 intake	Changes in rainfall are most critical (during both the dry and wet seasons), though temperature extremes can also affect crops.	Yields are declining for many of the crops grown using traditional forms of subsistence farming. Other aspects of community well-being are also vulnerable to climate, including transport, health, and water quality.	Climate impacts on agriculture will have social and economic impacts for the local community. They may also result in pressure on the NEA to review the PPA, and on HPL to increase the minimum flow. Generating output under all climate scenarios would decrease.	High confidence in the adverse impact on revenues if the minimum flow is increased.	HPL may wish to consider the following actions: 1. Provide support to local farmers for the construction of irrigation systems drawing water from tributaries of the Khimti Khola. 2. Actively support the development of alternative agricultural practices and crops. By encouraging the use of drought-resistant crops the need for additional irrigation may be reduced when compared with the needs for current agricultural practices.

TABLE 6: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR PACKAGES

Issue	Most important climate factors	Description of climate risks	Impact (including financial)	Confidence in the assessment	Recommended adaptation options
Engineering issues	Rising ambient temperatures have an impact on a range of operational processes, including (1) boiler efficiency, (2) steam turbine power output, (3) and the amount of power (surplus) for export. The efficiency of the company's gas turbine decreases as air temperature increases. The company's boiler efficiency, on the other hand, benefits from warmer temperatures. Three different temperature rises were considered as the basis for the engineering analysis: 1.1°C, 1.26°C, and 1.88°C. These values were chosen to provide a range of potential future temperatures by the 2020s, under different emissions scenarios and climate models.	Power output of the BSPM steam turbine with double extraction decreases slightly with an increase in cooling water temperature (these decreases are on the order of 0.07MW, 0.08MW, and 0.12MW, or 0.20%, 0.23% and 0.35%, respectively, for each of the scenarios modeled). The impact of air temperature increases on steam-fired boiler efficiency is positive but minor. The slight increase of the cost of generating power is offset to a small degree by the increase in efficiency of the boiler which will result in a reduction of the natural gas requirement for fuel.	Based on an assumed $14/MBTU and 340 operating days/year, higher temperatures lower natural gas costs (by increasing boiler efficiency) by $31,700–$53,000/yr by the 2020s. The increase in air temperature also results in a slight decrease in power output of the steam turbine of 0.20%–0.35% by the 2020s. The variable portion of the cost of electricity generation (unit cost) is also increased, because the amount of surplus power for export decreases. The reduction in revenue from reduced sales amounts to $57,000–$98,000/yr. The slight increase in the cost of generating power is partially offset by an increase in boiler efficiency, resulting in a reduction of natural gas required for fuel. The net effect amounts to $25,300– $45,000/yr by the 2020s. The total cost from the present day to 2017, (12% discount rate) is $157,000–$263,000.	**Overall: medium confidence.** High confidence in projections of higher temperatures. High confidence in the relationship between temperature, boiler efficiency and power output. This analysis presents the impact of a single, well-defined operational issue: temperature effects on turbine output and boiler efficiency. It relies on a number of assumptions (e.g., rough natural gas costs and electricity prices). The company will have a better idea of current climate sensitivities and existing engineering bottlenecks that limit operational capacity. The company will also have more robust information about the costs of operating the new turbine and of the sensitivity of the current system to changes in electricity costs.	Various adaptation measures could be implemented in order to manage temperature-related changes in assets over time, including reduction in available (surplus) power for export, such as (1) expanding the cooling tower to maintain cooling water temperature, or (2) increasing the condenser heat transfer area and/or increasing the cooling water flow to compensate for higher cooling water temperatures.

TABLE 6: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR PACKAGES

Issue	Most important climate factors	Description of climate risks	Impact (including financial)	Confidence in the assessment	Recommended adaptation options
Groundwater supply	Changing patterns of precipitation, which can have disproportionately large impacts on groundwater recharge rates. Packages' Report on Groundwater Studies for the proposed BSPM site concluded that groundwater resources are sufficient to meet operational needs in the current climate. This report did not take account of potential changes in future precipitation.	BSPM uses groundwater for all operations, and the area around Kasur is strongly reliant on groundwater resources (92% of the groundwater tube wells within Pakistan's Indus Basin Irrigation System are found in Punjab Province). Any decrease in groundwater resources would have serious consequences for the company itself and for the region around BSPM.	Despite uncertainty in projections of future precipitation for the region, an analysis using two different groundwater recharge modeling methods shows that a majority of climate models (at least 70% for the 2020s, and more by the 2040s) indicate an increase in natural recharge in the future. These modeled changes to future recharge indicate that it is unlikely that *supply* of groundwater resources will be depleted as a result of climate change over the lifetime of the project. It is not possible to estimate, however, how current demand from other users (see below) is depleting the groundwater aquifer.	**Overall: low confidence.** Low confidence in projected changes in regional precipitation. Low confidence in the effect of changing precipitation patterns on groundwater supply. High confidence that any decrease in groundwater supply would significantly affect both the company and the surrounding community. There has been very little research on the climate change impacts on global groundwater resources. This is identified as a priority area for research by the IPCC.	Given the uncertainty associated with current availability and future projections of groundwater, it would be very beneficial to perform an integrated assessment of groundwater resources that takes account of the needs of agricultural and other industrial users.

TABLE 6: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR PACKAGES

Issue	Most important climate factors	Description of climate risks	Impact (including financial)	Confidence in the assessment	Recommended adaptation options
Wheat yields	Rising temperatures and changes in supply of groundwater resources (see above). Agricultural climate risks are normally related to changes in precipitation and associated risk of drought. These factors are less important for Packages, as farms around BSPM are groundwater-irrigated and therefore much less susceptible to problems associated with changes in precipitation. Projections of future temperature show strong warming, with annual increases of 1.0°C–2.25°C by 2025. Over Pakistan as a whole, mean annual temperature has increased by 0.35°C over the period 1970–99. Extremes of hot weather have increased significantly since 1960.	The growth, development, and yield of wheat crops can be affected by climatic thresholds (e.g., periods of intense heat). Short-term extreme events, like exceptionally strong winds or floods, can also have negative impacts on crop productivity. In addition, compound climatic stressors (e.g., high temperatures combined with decreased rainfall) can increase vulnerability in the agricultural sector as a whole. Crop simulation models indicate that regions north of Kasur (in mid to high latitudes) will experience small increases in wheat yield with moderate increases in temperature (1°C–3°C), with additional warming having increasingly negative consequences for yield. In regions south of Kasur (low latitudes), these crop simulations indicate that even moderate increases in temperature are likely to result in decreased crop yields.	Wheat straw–fed lines account for only 35% of the total pulping capacity at BSPM, though Packages would like to increase this proportion. The wheat straw used at BSPM is groundwater-fed. The groundwater recharge modeling done for this study indicates that recharge rates are likely to increase rather than decrease as a result of climate change (though there is considerable uncertainty associated with this finding). Because of the diversification of its feedstock the company would not be significantly exposed in the event of a decrease in wheat crop production.	**Overall: medium confidence.** High confidence in projections of higher temperatures. High confidence in knowledge of links between changes in climate and crop yield. Low confidence in projections of changes in precipitation and changes in groundwater recharge.	The most sensible course of action for the company is to keep a watching brief and monitor the situation closely, so that the plant can source alternative feedstock if crop quality/quantity declines in future. The local community can adapt crop management processes to cope with projected changes in climate by • preparing for drought/wet events using seasonal forecasting; • using water more effectively and conserving soil moisture; • altering the timing and/or location of cropping activities to avoid hottest/driest weather; • adjusting fertilizer doses and irrigation to maintain grain quality that is consistent with the climate; • planting new varieties and/or species that are more appropriate to warmer and longer growing seasons.

TABLE 6: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR PACKAGES

Issue	Most important climate factors	Description of climate risks	Impact (including financial)	Confidence in the assessment	Recommended adaptation options
Changing demand for groundwater resources	Rising temperatures and changing patterns of precipitation. In arid and semi-arid central and west Asia (which contain some of the most vulnerable basins on the globe with respect to water stress) changes in climate and climate variability are already having an effect on freshwater demand, supply, and quality. Indicators showing current rates of water withdrawal given water availability show high to very high levels of water stress across Pakistan.	Climate changes have the potential to exacerbate existing pressures on water resources caused by population growth, industrialization, steady urbanization, and inefficiencies in water use. Unless water use is sustainable, residents of the region may experience a reduction in agricultural output and shortages of potable water, leading to considerable socioeconomic stress.	In the absence of detailed information on aquifer characteristics and other groundwater users, it was only possible to quantify groundwater recharge, or supply, rates (see above). Though groundwater recharge impacts are not estimated to present a significant risk to the company, climate-related changes to demand for groundwater in the area are expected to be large. One recent study shows that groundwater is being depleted at unsustainable rates across the Indian states of Rajasthan, Punjab (just across the border from Kasur), and Haryana. The study concludes that unsustainable consumption of groundwater for irrigation and other human use is likely to be the cause of depletion.	**Overall: medium confidence.** High confidence in projections of rising temperature, and high confidence that these increases will lead to increased demand for water Low confidence in projections of changes in precipitation High confidence that increased demand for water in the region (without corresponding increase in supply) will negatively affect the local population.	As above, given the uncertainty associated with current availability and future projections of groundwater resources, a very beneficial first step would be to perform an integrated assessment of groundwater resources that takes account of the needs of agricultural, industrial, and other local users.

TABLE 6: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR PACKAGES

Issue	Most important climate factors	Description of climate risks	Impact (including financial)	Confidence in the assessment	Recommended adaptation options
Community and social issues	Changes in rainfall are most critical, though temperature extremes can also affect crops. Flood events can cause significant disruption in the local area. Climate change also has the potential to result in increased risks of • soil erosion; • dryland degradation from overgrazing; • overextraction of the shallow groundwater resources accessed by farming communities (BSPM draws groundwater from much deeper wells); • forest fires; • loss of biodiversity; • vulnerability to new agricultural diseases and pests.	Adverse climatic conditions have the potential to negatively affect the crops grown by local communities, with consequences for rural livelihoods. Transport, health, and water quality and availability are also affected by a changing climate. The rural poor are particularly vulnerable to climate change because their livelihoods are rooted in the productivity of ecosystems, which are already being altered by rising temperatures and changing levels of precipitation. Despite a long history of coping with climate challenges, such as periodic droughts and floods, the rural poor also have limited capacity to adapt to climate change.	Climate impacts could have the following consequences for community and social issues: • Risk of perception that BSPM contributes to local water resource pressures; • Risk of general instability if local communities suffer as a result of climate change impacts; • Risk of poor and worsening health of staff; • Risk of migration of staff away to cities.	**Overall: medium confidence.** High confidence that climate change will negatively affect local communities and high confidence that the main climate-related risks have been identified.	BSPM has developed good relations with the local communities and it would be beneficial to maintain and to strengthen these. Below are a number of actions that could be beneficial in increasing the adaptive capacity of the local community: • Continue to support local wheat farmers with advice and technical support, particularly with regard to managing the potential impacts of a changing climate (e.g., information on heat- and drought-resistant crop strains); • Work with local communities and government to plan for and manage the additional pressures that climate change will place on water resources and infrastructure; • Take climate change impacts into account when designing company health care plans and facilities available to the wider public.

TABLE 7: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR GOPDC

Issue	Most important climate factors	Description of climate risks	Financial impact	Confidence in the assessment	Recommended adaptation options
Refinery and fractionation plant	Rising temperatures (annual increases of approx. 1.2˚C by the 2030s relative to the 1970-1999 baseline) are predicted for Kwae. Annual average temperatures rose by 1.5˚C over the period 1970-2007. A continuous water supply is also needed for refinery and fractionation operations.	The cooling systems for the refinery vacuum system and fractionation plant crystallizers were designed for a maximum cooling water temperature of 32˚C. By 2020, it is estimated that there could be a five-fold increase in the incidence of cooling water temperatures above 32˚C. This will lead to lower production rates of olein and stearin at both facilities. On average by the 2020s, the reduction equates to 3 days of lost production per year in the refinery and 2 days per year in the fractionation plant. Lack of water stops operations at the refinery and higher temperatures lead to increased water consumption. From January to May 2010, 3-4 days of refinery production were lost due to lack of water.	In the refinery, the estimated annual reduction in income from sales of olein and stearin is approximately $30,000 per year over the period 2010-2030 (12% discount rate). Assuming GOPDC would sell excess CPO instead, the net reduction in income is $3,600 per year for 2010-2030 (12% discount rate). For the fractionation plant, a further $28,000 per year of olein and stearin sales would be foregone (12% discount rate). Taking account of CPO sales, a net reduction in income of $3,400 per year is estimated for 2010-2030 (12% discount rate). Lack of water led to a loss of $26,000-$35,000 in income from the refinery, between January and May 2010.	**Overall: high confidence.** High confidence in projections of higher temperatures. High confidence in knowledge of links between temperature, refinery CPO throughput and olein and stearin output. Medium confidence in links between temperature and crystallization rates. High confidence in refinery income foregone due to lack of water in 2010. Low confidence in future changes in water availability.	When GOPDC increases the capacity of the refinery / vacuum system, they will take account of the climate change projections. Similarly, if any upgrades to the refrigeration and chiller system in the fractionation plant are undertaken, it is recommended to check design thresholds for resilience to climate change.

TABLE 7: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR GOPDC

Issue	Most important climate factors	Description of climate risks	Financial impact	Confidence in the assessment	Recommended adaptation options
Power plant	Rising temperatures and continuous water supply, as shown above.	The cooling system for the power plant turbine was designed for a maximum cooling water temperature of 32˚C.The efficiency of the condensing steam turbine reduces by 1% for a 1˚C temperature increase, leading to 1% higher fuel requirements to maintain power output. Warmer air will, however, be beneficial to the boiler, as less pre-heating will be needed.	As fuel is supplied as biomass waste, overall economics are not significantly affected. In a worst-case assumption where all GOPDC's annual diesel fuel use (1.13m litres) was for power production, a 1% increase would cost just $500 per year by the 2030s (12% discount rate, excluding tax). Increased water use for the power plant as temperatures rise will bring extra costs for water pumping and treatment. There may also be increased power plant maintenance costs, if higher temperatures increase dust levels.	**Overall: high confidence.** High confidence in projections of higher temperatures. High confidence in knowledge of links between temperature and power plant performance.	On the basis that fuel is free, no action is required.
Electrical systems	Rising temperatures	The performance and efficiency of electrical equipment is reduced by higher temperatures. Equipment fails more frequently and components may need to be resized.	A detailed study is required to evaluate the financial impacts.	**Overall: high confidence.** High confidence in projections of higher temperatures. High confidence that higher temperatures lead to reduced efficiency of electrical equipment, but the effect has not been quantified for GOPDC.	A detailed research study would help to establish the overall reduction in efficiency of electrical systems at GOPDC associated with rising temperatures and to identify whether any electrical equipment needs upgrading.

TABLE 7: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR GOPDC

Issue	Most important climate factors	Description of climate risks	Financial impact	Confidence in the assessment	Recommended adaptation options
Malaria	Annual rainfall which may increase or decrease by approx. 10-15% by the 2030s (relative to the 1970-1999 baseline). Total number of rainy days is also relevant (which may also increase or decrease).	Malaria is the most common illness reported at the GOPDC clinic. Higher rainfall and number of rainy days is correlated with an observed increased number of malaria cases two months afterwards. Increased annual rainfall, number of rainy days and rainfall intensity in future may lead to a rise in malaria cases due to increases in the amount of standing water and so improved breeding environments for the mosquito vector.	At present, annual revenues not earned, resulting from malaria illness, are estimated to range from $50,000 to $150,000. Additional costs include paying sick leave and costs of medical treatment (which varies depending on employment status of workers). Unless there are complications, treatment costs are only $0.50 per person. In 2007, treatment costs for GOPDC workers were about $370. Changes in malaria incidence due to climate change can not be predicted with confidence, due to uncertainties in future changes in rainfall.	**Overall: medium confidence.** High confidence that malaria already causes significant numbers of lost man days. Low confidence in projected changes in seasonal average rainfall. Medium confidence in projected increase in rainfall intensity.	GOPDC recognises the need to do spraying for malaria control more frequently. Working in partnership with local, regional and/or national authorities implementing malaria control programmes, and connecting with malaria early warning systems in the region may also be beneficial.
Local community livelihoods	Changes in rainfall are most critical, though temperature extremes can also affect crops.	Oil palm and other crops grown by local communities (cocoa, citrus, cocoyam, cassava, yam, and maize) are all negatively affected by drought, flooding/waterlogged soils and, in some cases, temperature extremes. Crops are rain fed. Other aspects of community well-being are also vulnerable to climate, including transport, health, water availability, and water quality.	Climate impacts on agriculture could have considerable economic impacts for the local community. In turn, lower incomes can have consequences for increased delinquency, prostitution, HIV/AIDS and child labor.	**Overall: medium confidence.** Only a qualitative assessment has been undertaken. There is good confidence that the main climate-related risks have been identified, but their severity is unknown.	GOPDC intends to support community awareness on climate change through the Community Development Committee which it funds.

TABLE 7: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR GOPDC

Issue	Most important climate factors	Description of climate risks	Financial impact	Confidence in the assessment	Recommended adaptation options
Worker health, safety and productivity	Temperature extremes and high humidity	Staff performance decreases at higher temperature and relative humidity, and accidents are more likely. This issue is most prominent at the mill and close to the power station turbine. More workers are already needed during the day shift at the mill, when temperatures are higher, than at night.	Due to higher temperatures, workers will need to take more / longer breaks. More workers may also be needed at the mill, with associated increased costs. It has not been possible to quantify this impact.	**Overall: medium confidence.** High confidence in projections of higher temperatures. Medium confidence that higher temperatures could lead to need for more workers at the mill.	As ambient temperatures increase, it may be necessary to consider having more mill workers and crane operators. It may also be necessary to consider building an enclosure for workers close to the turbine (as are found elsewhere) to shield them from high temperatures and/or to try to reduce the heat being emitted by the turbine.
Oil palm yield	Many climate variables influence yield, but changing soil moisture deficit (affected by changes in rainfall and rising temperatures) seems to be most important. Projections of changes in rainfall (and hence of hydrological deficit) for Ghana are uncertain.	If it occurs, reduced soil moisture would likely decrease oil palm yields. The effects of higher temperatures are uncertain—they reduce soil moisture but help fruit to ripen. Many climate-related issues affect different aspects of the oil palm lifecycle and hence yield. Given the complexity of the relationships, the impacts are difficult to analyze and model.	At present, annual fresh fruit bunch yields (tons/hectare) can vary by +/–50%. Climate plays a significant part in this variability. Modeling using climate change scenarios indicates that if fruit harvested from 1990 to 2006 were harvested in 2010–26, the estimated total change in revenue across this 17-year period would range from –$1.3 million to $34.7 million (undiscounted). For a mid-point year of 2018, annual projected revenue changes are in the range of –$27,000 to +$720,000 (12% discount rate). If fruit harvested from 1990 to 2006 were harvested in 2020–36, the estimated change in annual revenue for a mid-point year of 2028 would be in the range +$29,000 to +$280,000 (12% discount rate).	**Overall: low confidence.** Low confidence in projected changes in seasonal average rainfall. High confidence in projections of higher temperatures. Low confidence in ability to simulate impacts of climate change on oil palm yields. Low confidence in ability to calculate financial impacts, resulting from uncertain yield estimates.	The agricultural research organization, Cirad, recommended GOPDC improves soil structure in upland areas using empty fruit bunches. Research is needed into new seeds, better able to tolerate low rainfall conditions in Ghana. Palm Elite (an organization related to Cirad) produce new seed types.

TABLE 7: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR GOPDC

Issue	Most important climate factors	Description of climate risks	Financial impact	Confidence in the assessment	Recommended adaptation options
Pests and diseases	Extremes of wet and dry conditions emerge as the most important factors affecting the most destructive pest, the leaf miner (*C. lameensis*). As outlined above, climate change is expected to lead to increased rainfall intensity. Leaf miner larvae are also negatively affected by high temperatures.	Under conditions where the proportion of total annual rainfall that falls in heavy events increases, the *C. lameensis* leaf miner may be negatively affected (which may in turn lead to less destruction of oil palm yield). Higher temperatures might reduce the prevalence of leaf miner larvae.	Based on past experience of leaf miner outbreaks at GOPDC, estimated revenues not earned for 2009 and 2010 in the event of a heavy leaf miner attack range between $1.8 million and $5.3 million. Costs of pest and disease control also need to be considered. Changes in leaf miner incidence due to climate change can not be estimated.	**Overall: low confidence.** Low confidence in projected leaf miner attack likelihood and intensity. The literature linking climate to pest and disease occurrence lacks detail. Low confidence in knowledge of the impact of climate change on pest and disease occurrence.	Correlating observed climate data and leaf miner egg / larvae monitoring data, would help GOPDC to see how these factors are related. Similar correlations could be developed for other pests and diseases. This could potentially facilitate earlier detection of the risk of pest/disease outbreaks. Engaging in research on the relationship between oil palm pests and diseases and climate change would help GOPDC to understand the changing risks posed to oil palm production. According to the Ghana Environmental Protection Agency (EPA), once Ghana's Climate Change Adaptation Strategy is published, GOPDC can submit proposals for research on climate change impacts on pests and diseases of oil palm. Ghana EPA recognizes that these threats are not currently well understood.

TABLE 7: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR GOPDC

Issue	Most important climate factors	Description of climate risks	Financial impact	Confidence in the assessment	Recommended adaptation options
Ecosystem services	Total rainfall (projections for which are uncertain) is a key factor affecting the oil palm pollinator *E. kamerunicus*.	A reduction in total monthly rainfall may lead to a reduction in the number of *E. kamerunicus* present, with potentially negative consequences for oil palm yield. The impact of an increase in monthly rainfall is unknown due to a lack of information about the upper threshold that the pollinator can tolerate. GOPDC has never experienced any problems with low pollinator numbers.	A total loss of pollinators (which is the most extreme scenario) could lead to revenues not earned of \$1.2–\$1.4 million per year (undiscounted). The cost of assisted pollination would add to the financial impact of losing natural pollination services.	**Overall: low confidence.** Low confidence in relationship between climate and pollinator numbers, due to lack of detail in the scientific literature. Low confidence in projected changes in seasonal average rainfall. Low confidence in impact of climate change on pollinator presence and consequent impact on financial performance.	Linking in to research on ecosystem services and climate risks would be beneficial, such as the Oil Palm Research Institute's work on species that control leaf miner and research at the University of Oxford on the benefits of forest patches in oil palm plantations. Protection of BDPs may contribute to pest control, reduction of soil erosion and preservation of soil moisture. GOPDC should compare rainfall gauges close to Biodiversity Plots (BDPs) with those within plantation further away from BDPs, to see if BDPs make any difference to rainfall amounts. GOPDC should consider installing a full weather station at Okumaning, to ascertain if relative humidity there is higher than at Kwae, due to nearby forest. GOPDC can discuss with Mr Oppong, Ghana EPA as to the possibilities of gaining carbon credits for its BDPs. They may be eligible, depending on their size.

TABLE 7: HIGH-LEVEL SUMMARY OF THE ANALYSES UNDERTAKEN FOR GOPDC

Issue	Most important climate factors	Description of climate risks	Financial impact	Confidence in the assessment	Recommended adaptation options
Groundwater resources and wastewater	Primarily rainfall and temperature	Groundwater is essential for operations at the mill and refinery, and is used in the nursery. The aquifer used by GOPDC is fairly shallow, so it may be more vulnerable to changes in precipitation and temperature, as well as to over-exploitation by other water users. The development of the Newmont Ghana Akyem gold mine, 10km from the Kwae Estate, could potentially also affect the aquifer GOPDC uses. For wastewater treatment, higher temperatures may improve the efficiency of the anaerobic digestion process and hence the quality of the effluent. Changes in stream flow could be positive or negative. Lower stream flows would have less capacity to dilute effluent. Increasing stream temperatures could degrade water quality, by lowering dissolved oxygen concentration.	At present, GOPDC do not have an alternative water resource that could supply operations, and the financial impacts of a reduction in groundwater resource are severe. For the last two to three years, there has been some competition for groundwater resources between the nursery and the industrial operations, and in January to May 2010, 3-4 days of production at the refinery were lost due to lack of water. As temperatures increase, water consumption at the refinery, fractionation plant and power plant will increase. This will create additional stress on water resources as well as increased costs for pumping, filtering, softening and demineralizing water.	**Overall: low confidence.** Low confidence in projected changes in seasonal average rainfall. Low confidence in assessment of vulnerability of groundwater resources, owing to lack of information on the aquifer. High confidence in increased water consumption for industrial operations due to higher temperatures. Low confidence in assessment of impacts on wastewater management and stream water quality.	Given the criticality of water for operations at GOPDC, it is a high priority for the company to develop a better understanding of future water availability and to work together with other stakeholders to devise management strategies. It is recommended that GODPC engages with Ghana EPA and Newmont Ghana on how the new Akyem mine could affect groundwater resources. Newmont Ghana could be requested to undertake a hydrogeological assessment that encompasses GODPC's aquifer, to better understand the factors that influence its recharge. As well as investigating the mine's impact, this assessment should develop understanding of the relationships between GOPDC's aquifer and climatic variables, and it is recommended that GOPDC requests that the assessment incorporates the impacts of climate change. Monitoring the performance of the wastewater treatment system and stream quality as a function of climatic conditions would help to understand the criticality of the relationships.

Annex 3: Acknowledgments

We would like to thank the experts and members of the following institutions who have contributed to the elaboration of the Case Studies.

Khimti acknowledgments

Himal Power Limited (HPL)
SNPower
Department of Hydrology and Meteorology, Nepal
International Centre for Integrated Mountain Development (ICIMOD)
Indian Institute of Technology
Kathmandu University
Indian Institute of Tropical Meteorology
Kathmandu University
Alternative Energy Promotion Center
Butwal Power Company
Hydro-Solutions
Small Hydropower Promotion Project & Small Hydro Power Promoters' Association.
Khimti Area Cooperative (KREC)
Nepal Electricity Authority
Nepali Water Conservation Foundation
Department of Electricity Development
Ministry of Water Resources
Clean Energy Development Bank
Rural Energy Development Programme
United Nations Development Programme (UNDP) - Nepal
World Wildlife Fund (WWF) - Nepal
Khimti Neigbourhood Development Project
Local community representatives
Oxford University Centre for the Environment, UK
Centre for Ecology and Hydrology, UK
Reynolds Geo-Sciences Ltd, UK
Synergy, UK

GOPDC acknowledgments

Ghana Oil Palm Development Company (GOPDC)
GOPDC Outgrowers' Association
Siat Group
Oil Palm Research Institute
Kwaebibirem District
University of Ghana, Legon
Kade Agricultural Research Centre, University of Ghana
Agriculture-Engineering Department, Faculty of Engineering Science, University of Ghana, Legon
Department of Geology, University of Ghana, Legon
Department of Crop Science, University of Ghana, Legon
CSIR Water Research Institute
Ghana Meteorological Services
Food and Agriculture Organization (FAO)
Ghana Environmental Protection Agency
World Health Organization (WHO)
St Dominic's Hospital, Akwatia
Presidential Special Initiative, Ghana
Centre de coopération internationale en recherche agronomique pour le développement (CIRAD)

Packages acknowledgments

Packages Ltd.
WorleyParsons Canada
Oxford University Centre for the Environment

References

(For the complete list of references see individual case studies reports.)

Breure and Menendez. 1990. In *Rainfall impact on Oil Palm Production and OER at FELDA Triang 2*, ed. Muhamad Rizal.

Corley, R. H. V., and P. B. Tinker. 2003. *The Oil Palm*. 4th ed. Hoboken, NJ: Wiley.

IPCC (Intergovernmental Panel on Climate Change). 2007a. *Climate Change 2007: Synthesis Report; Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. R. K. Pachauri and A. Reisinger. Geneva: IPCC.

———. 2007b. *Climate Change 2007:The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Avery, M. Tignor, and H. L. Miller. Cambridge, U.K.: Cambridge University Press.

———. 2007c. *Climate Change 2007: Impacts, Adaptation and Vulnerability; Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson. Cambridge, U.K.: Cambridge University Press.

McSweeney, C., M. New, and G. Lizcano. 2008. "UNDP Climate Change Country Profiles—Ghana." School of Geography and Environment, University of Oxford. http://country-profiles.geog.ox.ac.uk.

Oboh, B. O., and M. A. B. Fakorede. 1999. "Effects of Weather on Yield Components of the Oil Palm in a Forest Location in Nigeria." *Journal of Oil Palm Research* 11 (1): 79–89.

Oki, T. 2005. "The Hydrologic Cycles and Global Circulation." In *Encyclopaedia of Hydrological Sciences,* ed. M. G. Anderson. Chichester, U.K.: John Wiley & Sons.

Willows, R. I., and R. K. Connell, eds. 2003. *Climate Adaptation: Risk, Uncertainty and Decision-Making*. Technical report. Oxford, U.K.: UKCIP.

International
Finance Corporation
World Bank Group

International Finance Corporation
2121 Pennsylvania Ave. NW
Washington, DC 20433
Tel. 1-202-473-1000
www.ifc.org/climatechange

The findings, interpretations, views, and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the Executive Directors of the International Finance Corporation or of the International Bank for Reconstruction and Development (the World Bank) or the governments they represent, or those of Himal Power Limited, Ghana Oil Palm Development Company, Packages Ltd, and the individuals and institutions listed in Annex 3.