Civil Society Guide to Healthy Rivers and Climate Resilience

International Rivers
people • water • life

October 2013

Civil Society Guide to Healthy Rivers and Climate Resilience

Published in October 2013 by International Rivers

About International Rivers

International Rivers protects rivers and defends the rights of communities that depend on them. With offices on four continents, International Rivers works to stop destructive dams, improve decision-making processes in the water and energy sectors, and promote water and energy solutions for a just and sustainable world.

Acknowledgments

International Rivers would like to express our deepest gratitude for our expert reviewers and contributors: Dipti Bhatnagar (Justiça Ambiental/Friends of the Earth in Mozambique); Geoffrey Kamese and Betty Obbo (National Association of Professional Environmentalists in Uganda); John Matthews (Conservation International in the U.S.); Himanshu Thakkar and Parineeta Dandekar (South Asia Network on Dams, Rivers, and People in India); and International Rivers staff members Peter Bosshard, Zachary Hurwitz, Samir Mehta, Ame Trandem, and Dipti Vaghela.

A special thanks to Jenny Binstock, Jennifer Larr, Alexandra Mendoza and Lindsay Miracle of UCLA's Luskin School of Public Affairs for their Master's report, which served as a basis for *Appendix 3: Key Questions for Assessing Climate Risks of River Projects*.

This guide was made possible through the generous support of the Clif Bar Foundation, the Kendeda Fund, and the Fund for International Rivers.

Publication Information

Written by Katy Yan and Lori Pottinger
Published by International Rivers

INTERNATIONAL RIVERS
people • water • life

2150 Allston Way, Suite 300
Berkeley, CA 94704, USA
Tel: +1 510 848 1155
Fax: +1 510 848 1008

internationalrivers.org

Design by Design Action Collective

Front Cover photo: A fisherman places a fish trap on the Mekong River. Photo: Thomas Munita
Back cover photo: On 14 March 2009, on the Ibanez River in Patagonia, Chile, local organizations celebrated their river and denounced the fact that local people were being denied water rights for local agricultural and ranching activities due to the control of water rights by EndesaChile. Photo: International Rivers

TABLE OF CONTENTS

Acronyms & Glossary 2

Introduction 4

How to Use This Guide 5

Chapter 1: The Value of Rivers 7

Threats to River Services 8

Protecting Rivers and Riverine Communities 8

River Basin Planning Solutions 9

Chapter 2: Understanding the Climate Risks to Rivers and Communities 10

Precipitation and Temperature 11

Floods and GLOFs 14

Glacial Lake Outburst Floods 14

Droughts & Higher Evapotranspiration 16

Hydropower Vulnerability 16

Maps of Climate Risks & Dams 19

Chapter 3: Assessing Climate Risks to Communities 22

Community-Based Adaptation 23

Assessing the Climate Risks of Planned and Existing Projects 28

Chapter 4: Addressing Climate Risks to Communities 30

Chapter 5: Finding Solutions to Adapt to Climate Change 36

Principles of Climate Resilience 37

Types of Solutions by Sector 39

Chapter 6: Conclusion 52

Appendix 1: Key Resources 54

Appendix 2: Climate Change Impacts on Rivers and Species 56

Appendix 3: Table of Key Questions for Assessing Climate Risks of River Projects 57

Appendix 4: Supplemental Work Sheet for Dam-Affected Communities 63

Endnotes 68

Fast Facts 69

ACRONYMS

CBA	Community-Based Adaptation
EIA	Environmental Impact Assessment
GCM	Global Climate Model, or Global Circulation Model
GHG	Greenhouse Gases
GLOF	Glacial Lake Outburst Flood
IPCC	Intergovernmental Panel on Climate Change
IRBM	Integrated River Basin Management
IWRM	Integrated Water Resource Management
MW	Megawatt
NAPA	National Adaptation Programs of Action
NGO	Non-governmental or Non-profit Organization
RCM	Regional Climate Model
SEA	Strategic Environmental Assessment
SEIA	Social and Environmental Impact Assessment
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WCD	World Commission on Dams

GLOSSARY

Climate adaptation: An adjustment in natural or human systems in response to actual or expected climatic impacts, which mitigates harm or seeks out beneficial opportunities. (IPCC)

Climate change: A change in climate that is attributed directly or indirectly to human activity, which alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. (UNFCCC)

Climate mitigation: Actions to limit the magnitude and/ or rate of long-term climate change. It usually involves the reduction in manmade greenhouse gas emissions.

Climate model: A numerical representation of the climate system based on its physical, chemical and biological components, their interactions, and feedback processes. The climate system can be represented by models of varying complexity. (IPCC)

Climate projections: A projection of the response of the climate system to various greenhouse gas emissions and concentrations scenarios, often based upon climate model simulations. Climate projections are different from climate predictions in that they depend on the types of scenarios used and their assumptions on future socioeconomic and technological situations. (IPCC)

Climate resilience: Efforts to strengthen key characteristics of complex systems, people and organizations to enable them to handle both anticipated and unanticipated stresses and shocks from future climate change.

Climate variability: Variations in the average state of the climate on all spatial and temporal scales beyond those of individual weather events. Variability may be due to natural internal processes within the climate system or to variations in natural or human-made external processes. (IPCC)

Community-based adaptation: A process based on a community's priorities, needs, knowledge and capacities, which should empower people to plan for and cope with the impacts of climate change.

Downscaling: A method that derives information for the local or regional scale from larger, global-scale models. Downscaling is used in top-down approaches to assessing climate risks.

Ecosystem services: Benefits that people obtain from ecosystems. These include provisioning services such as food, water, timber and fiber; regulating services that affect climate, floods, disease, wastes and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation and nutrient cycling.

Environmental flows: A system for managing the quantity, timing and quality of water flows below a dam, with the goal of sustaining ecosystems and the human livelihoods that depend on them.

Evapotranspiration: The transport of water into the atmosphere from surfaces, including soil, vegetation and bodies of water.

General circulation models: General circulation models, or GCMs, representing physical processes in the atmosphere, ocean and land surface are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. Scientists attempt to understand regional impacts by downscaling GCMs.

Indirect impacts: Impacts on the environment that are not a direct result of a project, but which are often mentioned in Cumulative Impact Assessments. Sometimes referred to as second or third level impacts, or secondary/tertiary impacts.

Integrated Resource Planning: A comprehensive and holistic methodology to plan a country's resource options that prioritizes energy efficiency and demand-side management, equally weighs the full range of feasible supply-side and demand-side options, and assesses them against a common set of planning objectives and criteria that have been agreed to based on a transparent and participatory process.

Integrated Water Resources Management: A process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resulting economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

Non-stationarity: The concept that due to climate change, past hydrological records are no longer a reliable indicator of potential future trends

No-Regrets Adaptation: Activities that can bring benefits (such as poverty alleviation or improved food and water security) even in the absence of climate change.

Precautionary principle: Where an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically. In this context, the proponent of an activity, rather than the public, should bear the burden of proof.

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change. (IPCC)

Risk assessment: The process of evaluating the risks associated with a particular hazard before taking some action. A climate change or climate risk assessment is the practice of identifying and evaluating the risks and effects of climate change on natural and human systems. Climate projections and on-the-ground observations are used to first identify how the climate is changing, and then the impact of those changes on systems such as river basin dynamics or community livelihoods are assessed, through, for instance, hydrologic modeling and community-level consultations.

River basin: Also known as a catchment, a river basin is a portion of land drained by rivers and tributaries.

Runoff: Water that is not absorbed into the ground but instead flows across the land and eventually runs into streams and rivers.

Sensitivity: Sensitivity is the degree to which a system is affected, either positively or negatively, by certain changes such as climate variability. The effect may be direct (such as a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (such as damages caused by an increase in the frequency of coastal flooding due to sea level rise).

Stationarity: The idea that future hydrology is predictable and can be based on past hydrological records, and that water-dependent infrastructure projects can be designed to be reliable.

Threshold: A level of magnitude at which sudden or rapid change occurs in a system. The climate system tends to respond to changes in a gradual way until it crosses some threshold. At the threshold, the change is more sudden compared to the changes that occur before or after the threshold and can lead to a new state.

Vulnerability: The degree to which a system is susceptible to, and unable to cope with, adverse effects of change, such as climate variability and extremes. Climate vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, as well as its sensitivity and adaptive capacity. A vulnerability assessment attempts to identify the root causes for a system's vulnerability to climate change.

The Baker River in Patagonia, Chile. Photo: Kate Ross

Introduction

Healthy, flowing rivers are the lifelines of our planet. They provide people with water, food, medicines, building materials, land-replenishing silts, navigation, recreation, and cultural and spiritual strength. Rivers and their catchments – and the rich variety of life they sustain – reduce the impacts of floods and droughts, support forests, recharge groundwater supplies, sustain fisheries, and maintain the ecological integrity of local ecosystems. For instance, the river's estuary, where fresh water mixes with the ocean saltwater, is one of the most biologically productive parts of the river – and of the planet. Most of the world's fish catch comes from species that depend for at least part of their life cycle on estuarine habitats.

Rivers and riverine ecosystems are also one of the most threatened in the world.[1] Historically, key stressors have included the over-extraction of water, pollution, diversions, and channelization. In the past 50 years, the amount of runoff flowing into rivers has changed substantially in many basins due to the combined effects of withdrawals, dams, and climate change.

Climate change does not affect all parts of the water cycle equally, nor does it impact freshwater ecosystems or water resource management (or even all regions) evenly. Climate change is also not always experienced in a negative way by people and the species dependent on freshwater resources. However, long-standing intensive human use and alteration of lakes, rivers, and wetlands, combined with the quickening pulse of climate change, has resulted in many negative impacts.

In many cases, human impacts such as pollution and over-extraction have had far more serious negative impacts than climate change on freshwater ecosystems and species. However, the importance of climate change impacts on river systems – and especially how it can amplify human modifications to the natural system – is becoming increasingly important as riverine communities become more vulnerable to both. This guide is intended to help explain and suggest ways to manage these negative impacts.

Two current impacts of climate change on aquatic systems are especially important to address: climate change can intensify existing problems of poor water resources management (for example, reducing water quality and lowering water availability), and it can profoundly alter key ecological and hydrological qualities (for example, altering fundamental flow regime qualities). Climate change is now beginning to shift from its current role as an "intensifier" to a widespread fundamental driver of changes to ecosystems, with the potential for ecological and economic impacts comparable to the worst of previous human interventions.

In response, many public and private institutions have developed projects and programs for climate adaptation at both the national and local levels. These responses often represent two different modes of development: one based on top-down decision-making framework, traditional water development projects and large infrastructure projects such as large dams and diversions, and another that uses a bottom-up, community-based, decentralized framework.

While it will be necessary to have adaptation projects and programs at several scales, as well as partnerships among many types of user groups, to address the impacts of climate change, unfortunately, the top-down large infrastructure model is currently dominating many national and international debates on development – and thus decisions on how to prioritize limited adaptation and mitigation funding. In contrast, the most successful projects and programs are those that are grassroots driven and include community participation at every step of the process. Only in this way can adaptation practitioners fully understand the needs, capacity and vulnerabilities of affected communities to climate risks, and effectively deliver solutions that meet those needs while empowering stewardship of local resources.

International Rivers' experience in the movement to protect rivers has made us keenly aware of the importance of civil-society-developed informational resources for use by community-based organizations. With the help of a number of partner organizations, we have developed this *Civil Society Guide to Healthy Rivers and Climate Resilience*, which summarizes how climate change is impacting rivers and provides some tools that we hope will be useful for those working with riverine communities to build their resilience to climate change. While there are many information sources on building climate resilience, this guide focuses on river resources and some of the key infrastructure projects, especially large dams that could impact riverine communities' ability to adapt to a changing climate.

Activists march through the town of Temacapulín, Mexico during Rivers for Life 3: The Third International Meeting of Dam Affected People and Their Allies in 2010.

HOW TO USE THIS GUIDE

The guide begins with an introduction to the role of rivers and their services in sustaining both local and global functions, as well as major threats to these resources. Chapter 1 sets the scene and describes why protecting rivers is important in a warming world. Chapter 2 provides the background on a range of climate-change risks that river systems and river-dependent communities and economies can expect, in order for users to begin to **understand** the types of risks they may be facing. Chapters 3, 4 and 5 will lay out the key recommendations and resources necessary for users to **assess** (Chapter 3), **address** (Chapter 4), and find the solutions to **adapt** (Chapter 5) to a world of increasing climate risks.

Throughout each chapter, we offer case studies and examples from around the world on successful adaptation projects, specific climate risks to a particular basin, key issues and concepts, and other topics. Sources for the facts listed in the sidebars can be found on the back inside cover.

A set of key recommendations (found in Chapters 3-5 and summarized in the conclusion) will help guide users in evaluating how dams and other water and energy-sector projects in combination with climate change might impact the climate resilience of local communities. In the Appendix, you will find a table of key questions to ask decision-makers when evaluating a particular dam project for its potential climate risks, as well as a list of resources and regional worksheets you can modify and use for conducting climate adaptation trainings in your specific region.

With such broad and complex topics as rivers and climate adaptation, this guide is not meant to be comprehensive or prescriptive. There will be limitations to implementing some of our recommendations depending on your local context. In addition, while this guide is focused on adaptation, we recognize that ensuring that all countries promote a low-carbon development path and drastic cuts to carbon emissions (especially for the biggest polluters) remains a critical and difficult to solve issue. Without such "climate mitigation," adaptation practices will have limited impact. While mitigation is beyond the scope of this guide, many of the tools included here are applicable to projects that are supposedly efforts at mitigation.

Finally, we hope that the tools and recommendations in this guide will help you chart a path towards assessing and addressing the particular climate risks that your river basins are facing. Whether it's evaluating a government infrastructure project for its climate risks to a river system, or developing a new adaptation project, we hope that this guide will allow you to effectively advocate for the climate resilience of your river basin community.

Contact us!

This guide is an evolving document. If you have a question, correction, case study or other suggestions on how to improve this guide, please send it to Ms. Lori Pottinger, lori@internationalrivers.org, and Ms. Dipti Vaghela, dvaghela@internationalrivers.org. If you have a suggestion for a translation of the guide or have questions about how to conduct regional trainings based on this guide, please feel free to contact us as well.

Children jumping into the Tapajós River in Brazil. Photo: Brent Millikan

The Value of Rivers

Rivers, floodplains, wetlands and water bodies provide a number of key climate and ecosystem services, including protection against flooding, enhancement of water resources, and capturing carbon, to name just a few. The world's major tropical rivers also support forests that act as critical carbon sinks (although the triple threat of climate-induced droughts, fires and land changes that lead to deforestation threaten to turn some tropical carbon sinks into carbon sources). Rivers maintain forest ecosystem health by depositing soil along the entire length of a river network, from source to delta. When it reaches the ocean, soil deposition supports marine food chains, contributes to the ability of oceans to absorb carbon dioxide (CO_2), and builds coastal ecosystems that naturally aid in reducing the risks of major storms.

Some major rivers – including the Amazon, Congo and Mekong – play a surprisingly large role in helping tropical oceans absorb carbon. The vast flow of major river basins delivers phosphorus, iron and other nutrients far offshore, where they are consumed by certain forms of sea life such as phytoplankton. These microorganisms "fix" or take carbon out of the atmosphere. The organisms eventually sink, taking carbon with them to the deep seafloor.

Dams could change the delicate workings of this ecosystem service by holding back the river-borne and nutrient-rich sediment that feeds this cycle. Scientists predict that damming these high-flow, high-sediment rivers in warm-ocean areas could reduce their ability to mitigate climate change. For instance, a 2009 study on Africa's biggest proposed hydropower project, the Grand Inga Dam on the Congo, says that "plans to divert, store or otherwise intervene in Lower Congo River dynamics are truly alarming" and "ignore the river's significant influence on the equatorial Atlantic, which, in turn, is central to many climate change models."[2]

The wealth of ecological services provided by river systems that sustain life on earth are rarely given much weight in water and energy planning processes, however, even though they are of critical importance for adapting to climate change. The 2005 Millennium Ecosystem Assessment concluded that efforts to reduce rural poverty and eradicate hunger are critically dependent on ecosystem services such as those provided by rivers, particularly in Sub-Saharan Africa.

THREATS TO RIVER SERVICES

Large water infrastructure projects – including storage and large run-of-the-river dams, basin transfer schemes, and river channelization – can cause considerable harm to ecosystem services and livelihoods by altering the hydrological cycle. When the impacts of climate change combine with these infrastructure-related impacts, the scenario becomes a "perfect storm" for the world's fisheries, forests, critical natural habitats, and agriculture,[3] while creating or worsening tensions between various water users upstream, alongside and downstream of infrastructure projects.

Despite these risks to river services, countries are planning and building major diversion projects intended to deliver water from water-rich regions to distant arid regions, such as China's South-North Water Transfer Scheme and India's controversial river linking project. The environmental and social impacts of these massive engineering projects, especially for downstream water users, have been largely ignored – as have the impacts of climate change on the reliability of river flow in the now-wetter regions.

In addition, the construction and operation of large dams and diversion projects can irreversibly harm a community's right to a healthy environment, to human health, to food, to religious practices, and to culture. They can also result in forced displacement and all the turmoil that brings, and violate indigenous peoples' rights to land and natural resources.

PROTECTING RIVERS AND RIVERINE COMMUNITIES

Thus far, traditional development strategies that have depended on technological fixes and top-down approaches have had little success in reducing poverty and preparing vulnerable populations for weather-related disasters. As the impacts of climate change become more urgent each day, it has become clear that cross-cutting approaches that combine community-based development, disaster-risk management and climate adaptation are more important than ever.[4] Healthy rivers are critical for helping vulnerable communities adapt to a changing climate – protecting them now is a community's health insurance policy for the future.

Community-Based Adaptation

One of the more sustainable ways of protecting riverine communities and river resources from climate impacts is through community-based adaptation (CBA). CBA is a process that is meant to empower people to plan for and cope with the impacts of climate change from the ground up. As its name suggests, it is also firmly based in a community's priorities, needs, knowledge, vulnerabilities and capacities. It asks the questions: (1) how do you include everyone in the community during the planning, assessment, design, implementation and evaluation stages of an infrastructure project, and (2) what tools and sources of information are available to ensure that projects are the most effective for meeting community needs? Using a CBA approach to address the risk of increasing floods, for example, might involve the community mapping out areas that are most prone to flood damage, creating a local disaster management plan, and developing green infrastructure projects such as restoring degraded floodplains so that they can better store flood water and recharge streams and aquifers.

In the long term, in order to effectively implement CBA activities and connect community-based decisions with broader regional and national decision-making, government institutions and programs must be strengthened, and capacity building for local communities and civil society activists must occur. At the same time, while the CBA approach acknowledges the important role that outside expertise and skills can play in developing climate-resilient projects or programs that minimize negative environmental and social impacts, it is grounded in local participation and community knowledge. By operating under this fundamental principle, a chosen project or program is much more likely to meet local needs now and in the future. (See Chapters 3 and 4 on **assessing** and **addressing** climate risks as part of the CBA process.)

RIVER BASIN PLANNING SOLUTIONS

Unlike engineered river systems, free-flowing streams have tremendous capacity to adjust to changes in water discharge and inflows of sediments (both of which are expected to change in many areas under future climate scenarios). This concept is critical for understanding how to reduce climate risks in a changing climate. River basin planning and management strategies at the national and international policy levels that seek to protect free-flowing rivers or ensure well-planned "environmental flows" from dammed rivers can increase the resilience of riverine ecosystems and populations that are especially vulnerable to climate change.

River basin planning that restores or preserves a river's natural features not only contributes to overall ecosystem resilience, but also produces important benefits for people. Riparian wetlands and floodplains help store water and thus reduce flooding, while also helping to recharge groundwater, which means more water will be available in the river and for people during dry periods. To accomplish this, government planners may need to give the river more room to flood by removing infrastructure from floodplains and allowing vegetation to grow back. According to many water experts, such practices can save both money and lives if enacted now rather than after a flood or other climate-related disasters occurs.[5]

China Dams the Upper Mekong River

The Mekong River, known as the *Lancang Jiang* in China, is the heart and soul of mainland Southeast Asia. While countries in the lower stretch of the river have yet to complete a dam on the mainstream Mekong, China already has over 20 planned and seven existing large dams on the Upper Mekong. Despite concerns over water security, fish migrations, climate change and sedimentation, China has yet to release any significant information about its dams to its downstream neighbors.

Since the early 1990s, academics have linked changes to the Mekong River's daily hydrology and sediment load to China's dams. These dams have begun to drastically change the river's natural flood-drought cycle (the "flow regime") and block the transport of sediment, which is expected to affect ecosystems and the livelihoods of millions living downstream. Impacts on water levels and fisheries have already been recorded along the Thai-Lao border.

In addition, climate change is expected to increase tensions among the various stakeholders of this critically important river. Hydrological changes that will affect rivers and dams include a reduced seasonal snowpack in the Tibetan Plateau, shifts in winter precipitation and timing of snowmelt, and increased evaporation in reservoirs. Extreme rainfall events, an increase in intensity and frequency of floods and droughts, and a continued deterioration of water quality are all expected to occur. The unstable changes in the intervals of floods and drought will have severe impacts on regional economic activities, not to mention increase pressure on China to store more water upstream for its own use.

The 1,750 MW Jinghong Dam on the Lancang River was completed in 2009. Photo: International Rivers

As a result of these concerns, NGOs in China and Southeast Asia are calling for more transparent transboundary basin management and smarter energy and water resources planning in China that does not sacrifice its rivers.

For more information, see:
www.internationalrivers.org/node/2318

Fishing boats on the Sesan River in Cambodia. The river's fishery has seen dramatic losses as a result of dam construction. Photo: International Rivers

Understanding the Climate Risks to Rivers and Communities

The impacts of climate change on freshwater ecosystems will be complex and difficult to predict. These impacts will lead to changes in the quantity, quality, and timing of river flows. Some of these changes are already having major effects on freshwater ecosystems around the world, including:[6]

- Shifts from snow to rainfall, and changes in the timing of snowpack melting
- Alteration of surface runoff and groundwater recharge patterns
- Shifts in the timing of floods and freshwater pulses, and more frequent and intense floods

- Increased evaporation, especially from shallow water bodies and reservoirs
- Saltwater intrusion in coastal and delta areas from rising sea levels
- More intense runoff events, which can lead to increased sediment and pollution loads
- Increased extremes in water temperatures
- More intense and/or frequent droughts

For a comprehensive table of expected and existing impacts, see *Appendix 2: Climate Change Impacts on Rivers and Species*.

River flows are becoming more unpredictable, and "extreme" events such as floods and droughts more common. These changes can have cascading effects on forests, fisheries, a river's shape and delta, and widespread impacts on local economies and communities. Dams can worsen some of these impacts: bigger floods threaten the safety of dams, and their operation during large floods can put people at risk from sudden dam releases. Longer droughts can greatly reduce hydropower and water supply. Salt-water intrusion due to dams withholding sediments downstream, combined with sea level rise, could harm water quality. Increasingly heavy rain and floods can wash pollutants into water sources, or damage water supply systems. A specific basin's vulnerability will depend on the scale and types of water infrastructure in that basin, the scale of deforestation, and other development in the basin.

There is no agreed-upon way to design, manage, and operate dams in a changing climate. Today, most dams have been designed according to the assumption that climate and hydrological patterns are "stationary" (in other words, reliable and predictable based on past events and characteristics).[7] However, this assumption fails under the current climate change scenario. Continuing to depend upon this assumption can leave dams highly vulnerable to even small shifts in climate regime. If a climate change or climate risk assessment were conducted so that a dam design took into account multiple potential futures, the dam would likely need much greater capacities to safely pass high floods, and projections of power generation for hydropower projects would have to allow for the probability of new extremes of drought. These factors could increase its costs and reduce its benefits, potentially making alternatives to the project more attractive.

This chapter offers a summary of some key risks to rivers, riverine communities, and dams in a warming world. A climate risk assessment for any river project should consider each of these major impacts.

PRECIPITATION AND TEMPERATURE

The effects of climate change on rivers are already becoming apparent as major changes in river discharge now affect watersheds around the world. Increasing temperatures will mean that globally, more precipitation will fall as rain rather than snow (though the amount will vary geographically and temporally). Areas that have substantially higher rainfall or that will have more intense storms will experience more flooding, especially in areas with fewer riparian wetlands and forests along rivers, both of which act to capture floodwater and release it more slowly. Regions that are expected to experience less precipitation will have more severe and longer droughts.

Higher precipitation can also lead to a deterioration of water quality, leading to significant impacts on food security and increasing the vulnerability of poor rural farmers, especially in the arid and semi-arid tropics and in Asian and African mega-deltas.[8] Heavy downpours can increase the amount of runoff into rivers and lakes, washing sediment, nutrients, pollutants, trash, animal waste, and other materials into water supplies, making them unusable, unsafe, or in need of water treatment. More intense dry periods can also alter the concentration of nutrients and pollutants, turning freshwater systems into toxic soups (such as in the Murray-Darling Basin in Australia, which has been experiencing a decade-long drought).

Changes in water temperatures are more difficult to predict. In some areas, water temperatures have been rising, while in places where there is greater snowmelt or higher levels of precipitation, water temperatures may be decreasing.[9] Increases in water temperature will affect riverine fisheries. If river water warms 3-4° Celsius (C) in the next 25 years, the organisms living in them may not be able to adapt fast enough to cope. At first, there may be fewer offspring or fewer young surviving. Over time, populations of some species will decline, while those species able to withstand warmer water (often non-native species) will increase. If deforestation or damming has occurred in a watershed, temperature increases above historic levels will be far greater and ecologically more harmful.[10] During past periods of climate change, many species responded to shifts in water conditions by moving to nearby basins. However, given the scale of alteration humans have had on rivers globally, these shifts are less likely to succeed.

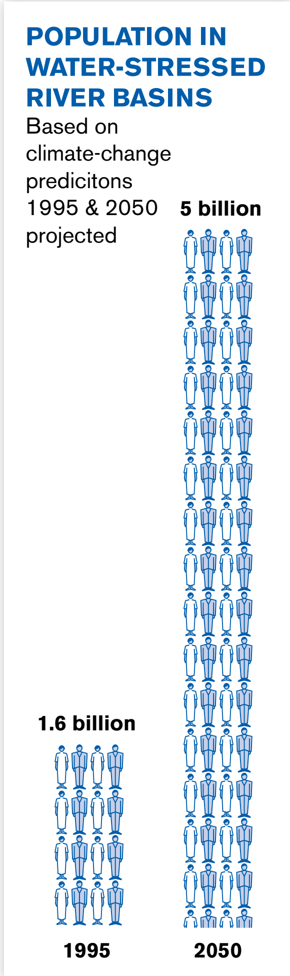
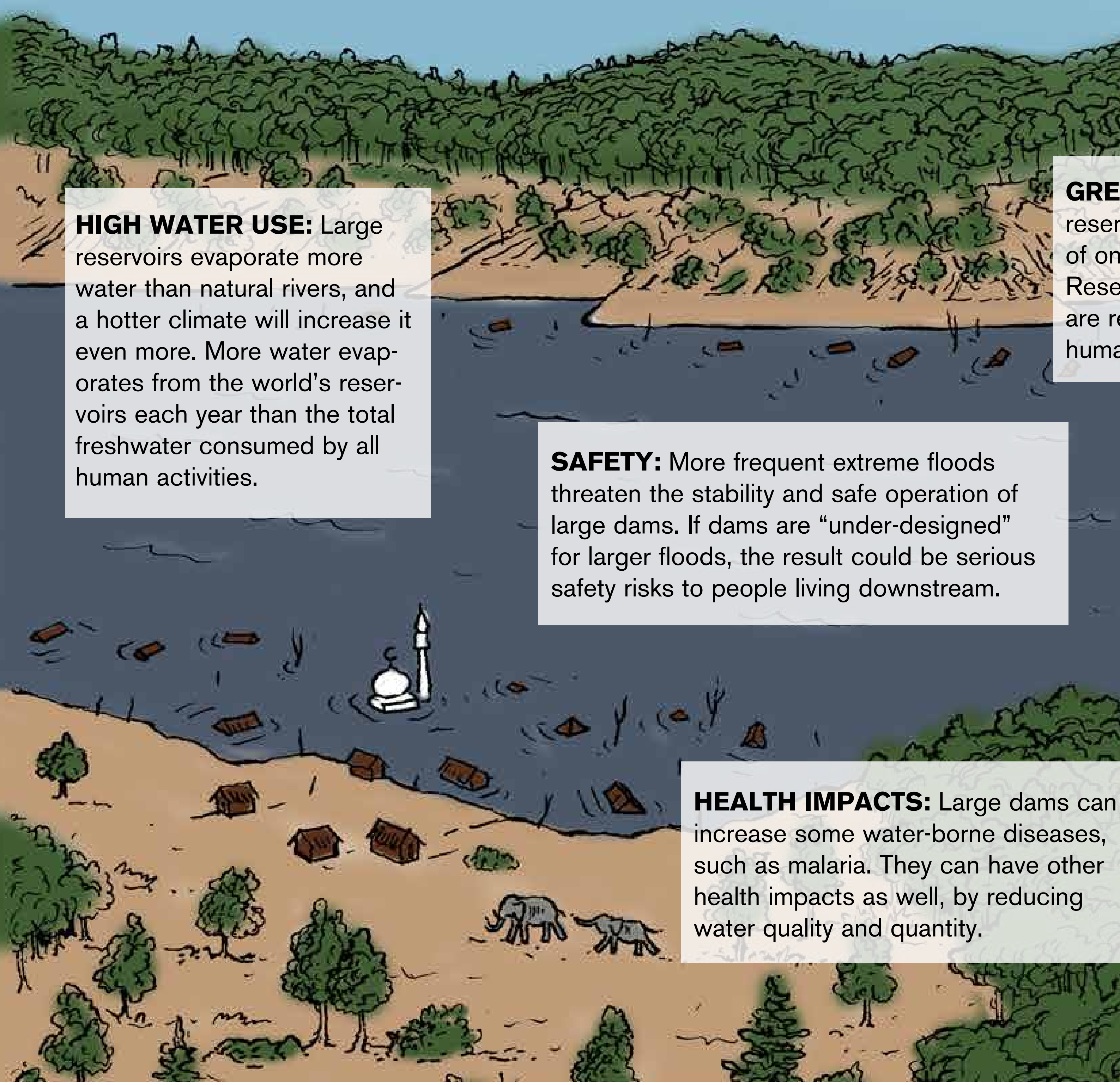


Figure 1: Population in water-stressed river basins, based on climate change predictions. Source: Black, M. and King, J. The Atlas of Water: Mapping the World's Most Critical Resource, 2009.

Dams and Climate Change

Dams are very vulnerable to climate change. In addition, they can worsen some negative impacts of climate change, which can reduce the ability of river ecosyster and communities to adapt.

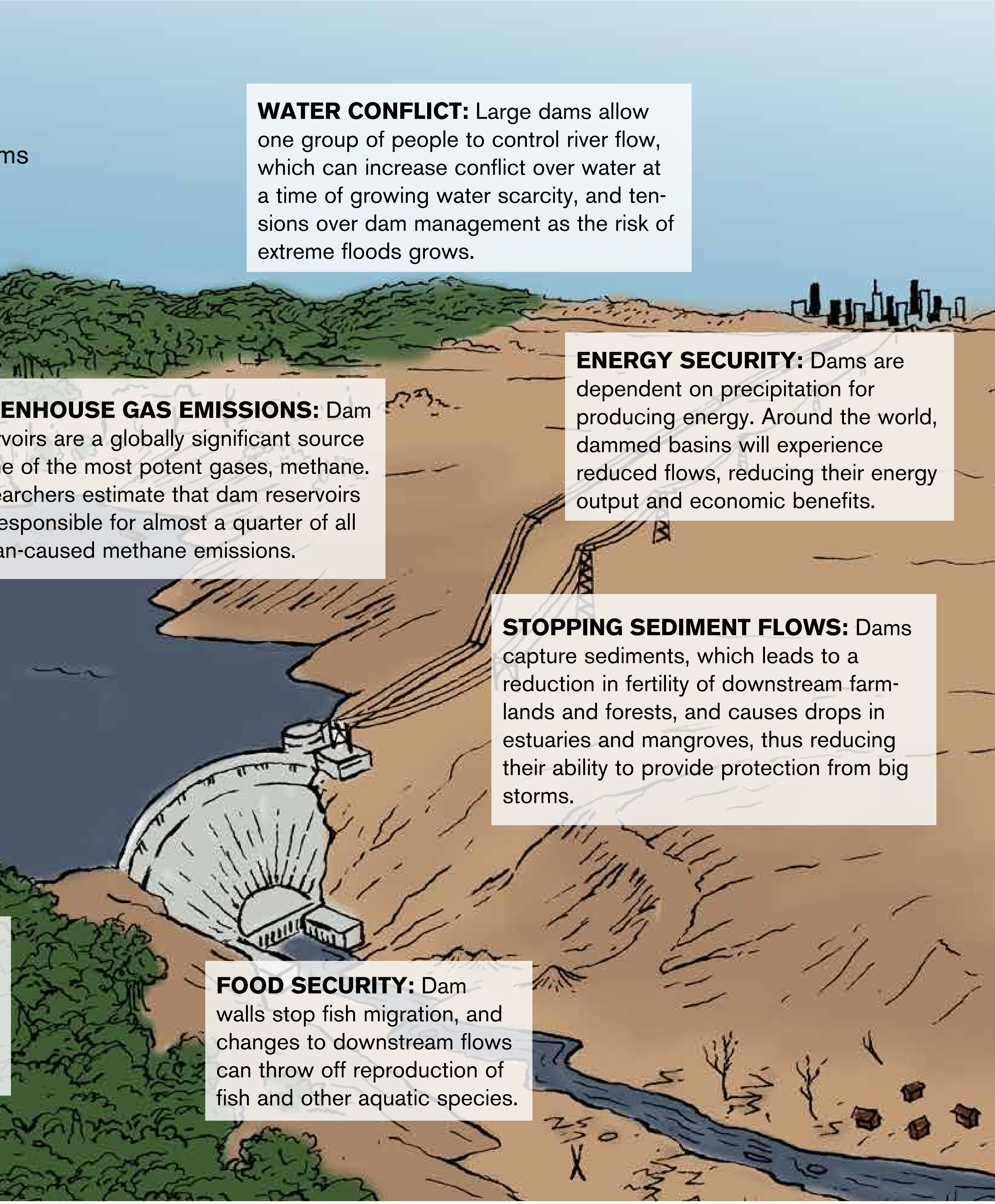


HIGH WATER USE: Large reservoirs evaporate more water than natural rivers, and a hotter climate will increase it even more. More water evaporates from the world's reservoirs each year than the total freshwater consumed by all human activities.

GRE
reser
of on
Rese
are re
huma

SAFETY: More frequent extreme floods threaten the stability and safe operation of large dams. If dams are "under-designed" for larger floods, the result could be serious safety risks to people living downstream.

HEALTH IMPACTS: Large dams can increase some water-borne diseases, such as malaria. They can have other health impacts as well, by reducing water quality and quantity.


ms
WATER CONFLICT: Large dams allow one group of people to control river flow, which can increase conflict over water at a time of growing water scarcity, and tensions over dam management as the risk of extreme floods grows.
ENHOUSE GAS EMISSIONS: Dam
rvoirs are a globally significant source
e of the most potent gases, methane.
earchers estimate that dam reservoirs
esponsible for almost a quarter of all
an-caused methane emissions.
ENERGY SECURITY: Dams are dependent on precipitation for producing energy. Around the world, dammed basins will experience reduced flows, reducing their energy output and economic benefits.
STOPPING SEDIMENT FLOWS: Dams capture sediments, which leads to a reduction in fertility of downstream farmlands and forests, and causes drops in estuaries and mangroves, thus reducing their ability to provide protection from big storms.
FOOD SECURITY: Dam walls stop fish migration, and changes to downstream flows can throw off reproduction of fish and other aquatic species.

Regions that depend on melt water from major mountain ranges contain one-sixth of the world's population.

By 2080, 20% of people will live in areas with increased flood risk.

Snowmelt Runoff

Water volume stored in glaciers and snowpack is declining, resulting in decreases in seasonal flows in affected areas. Shrinking glaciers will cause long-term declines in glacial runoff and alpine stream flow during the melting season. This will reduce the hydropower output during the melt season, especially for many Andean and Himalayan countries, as well as the amount of water available for household use, irrigation, and groundwater recharge.

Snowpack, which unlike glaciers accrues and is lost on an annual basis, is very sensitive to temperature and is a major contributor to runoff in alpine regions. Change in the seasonality of runoff due to climate change is becoming more widespread. For instance, in most mountainous regions, snowfall has decreased while rain has increased, leading to lower snowpack accumulation in winter, along with faster spring melting. Runoff is likely to increase at higher latitudes and in some wet tropics, including East and Southeast Asia, and decrease over much of the mid-latitudes and dry tropics, including many areas that are currently water stressed. The combined reduction in runoff and river flow as a result of lower precipitation will negatively affect the production of electricity from hydropower dams.

In addition, the effect of more-rapid snowmelt on potential flooding is a major risk factor for millions of people around the world. Rapid snowmelt can also trigger landslides and debris flows. In combination with specific weather conditions, such as excessive rainfall on melting snow, it may even be a major cause of floods. In Switzerland, snowmelt forecasting is being used as a flood-warning tool to predict snowmelt runoff and potential flooding.[11]

FLOODS AND GLOFS

Climate change has led to a rise in extreme weather events, including higher-intensity hurricanes and heavier rainfall in many parts of the globe. Coupled with rising sea levels, intensifying storms can increase coastal flood damages.

In addition to being deadly for inhabitants in their path, floods can cause a variety of problems, including contaminated drinking water, pollution spills, increased populations of disease-carrying insects and rodents, and disruption of community life and local economies. Floods can also damage critical infrastructure like sewer systems, triggering sewage overflows that can spread into local waters.

More frequent extreme floods also threaten the stability and safe operation of large dams. Dams are designed using historic hydrological variables, such as average annual flow, annual variability of flow, and seasonal distribution of flow. As temperatures warm, however, historic data is increasingly unreliable for dam design. If dams are "under-designed" for larger floods, the result could be serious safety risks to those living downstream of large dams.

The flood risks of large dams are made worse by increasing sedimentation. Larger sediment loads carried by increasingly extreme rainfall can block dam spillways and take up room in the reservoir that could otherwise hold floodwaters.

Many hydropower projects are justified on the basis of providing flood control in addition to energy generation. However, allowing for flood storage means the reservoir must be drawn down to provide flood capture space usually at the same time that water is needed to supply energy. Another problem is that most existing and proposed dams are not designed to handle extreme floods, which are becoming more common in our warming world. This can result in costlier damages than before the dam was built, as more people move into the floodplain and assume it is safer now that a dam exists; when the dam cannot contain the new, larger floods, it can lead to devastation in the now-populated areas.

Floods caused by dam failures and poor management of dams during extreme weather events are already a serious problem in many regions, and are expected to increase. Flood damages have soared in recent decades, despite hundreds of billions of dollars spent on flood control structures. For example, Cameroon is experiencing increasing flooding, which has caused dams to overtop, thus worsening natural flood impacts. In 2012, flood releases from Lagdo Dam resulted in many deaths and huge displacement in downstream Nigeria. Dams are becoming harder to manage as climate change makes rainfall more unpredictable, yet new dams are going to be built that have not been planned with this risk in mind.

GLACIAL LAKE OUTBURST FLOODS

The sudden bursting of glacial lakes, known as glacial lake outburst floods (GLOFs), poses serious risks of flash flooding to downstream communities and ecosystems in some mountainous countries, and for the safety of dams built in these regions. As glaciers melt under a warming planet, they can form large lakes behind temporary dams of ice and rock. When these natural dams collapse, millions of cubic meters of water can be released in massive flash floods.

The Himalayan region – which is experiencing climate change faster than any other region in the world – is currently experiencing a dam boom that could put millions of people at risk from catastrophic floods and dam breaks. The Dig Tsho GLOF in Nepal in 1985 was one of the most devastating in recent history. The bursting of this glacial lake near Mount

India's Himalayan Floods a Manmade Disaster

By Himanshu Thakkar, Director of the South Asia Network on Dams, Rivers and People, Delhi, India

The Northern Indian Himalayan state of Uttarakhand experienced widespread flash floods and landslides in June 2013. At least 1,000 people were confirmed dead, thousands more remain missing, 147 bridges were washed away, and more than 10 hydropower projects damaged or destroyed. One rough estimate put damages at US$50 billion.

Because it is young mountain system, Uttarakhand is inherently vulnerable to natural disasters such as cloudbursts, landslides, flash floods, glacial lake outbursts and earthquakes. Climate change is increasing the frequency of such disasters.

At the root of these floods was a wonton disregard for the "carrying capacity" of this fragile area's natural systems. The human-induced assault included unregulated, unsafe and unplanned infrastructure development along local rivers, including the development of a large number of hydropower projects built in the fragile zone without proper checks and balances.

In the first decade of the new millennium alone, more than 15,000 hectares of forestland have been legally diverted in the state for various projects. More than 1,600 hectares of riverbed mining were given legal sanction in the same period. During this time tourism increased by up to 380%. Uttarakhand has at least 51 existing hydropower projects of various sizes, another 47 under construction and 238 planned. As a post-disaster report from the National Institute of Disaster Management confirmed, all these activities have significant environmental and social impacts that hugely increased the disaster potential of the area.

As Uttarakhand now turns toward rebuilding and rehabilitation, it needs to accept its past mistakes and make urgent amends. Some top priorities should include:

- Initiating cumulative impact assessments and carrying capacity studies in all river basins.
- Putting a stop to hydropower projects that are planned and under construction.

Severe flash floods swept through the Northern Indian state of Uttarakhand in 2013, destroying several hydropower projects including the Vishnuprayag Dam. Photo: Matu Jansangthan

- Demarcating the path of all rivers, declaring no construction zones around them and preparing time-bound plans for the relocation of buildings at risk.
- Ensuring an active disaster-management department that has a key role in decision-making about all new developments.
- Putting in place credible environmental governance and compliance systems along with robust systems for warning, forecasting, monitoring and information dissemination.
- Assessing the vulnerability of infrastructure and people in the changing climate.

This disaster can be taken as a rather costly and tragic wake-up call for Uttarakhand and all Himalayan states and countries. If it is not heeded, what we have seen may turn out to be just a "movie trailer" for the full feature film that is yet to come.

For a full version of this article, see: www.internationalrivers.org/node/8037

Everest caused a huge flood wave that travelled down the valley, killing five people and destroying one hydropower station, damaged many acres of cultivated land, and took out 14 bridges.

In January 2009, the government of Bhutan identified more than 2,600 glacial lakes in the country, of which 25 are considered to be at high risk of bursting, according to Yeshi Dorji of Bhutan's Department of Geology and Mines. While Bhutan is aware of the risk of GLOFs and is improving its early warning system, it is also constructing one of the largest hydropower dams in the region – the 90-meter-high Tala project on the Wangchu River – and has plans for more large dams.[12] These projects could undermine its program to reduce the risks of GLOFs.

170 cubic kilometers of water evaporates from the world's reservoirs every year.

DROUGHTS & HIGHER EVAPOTRANSPIRATION

Many parts of the world are predicted to have less rain, higher temperatures and higher evaporation rates, as well as more severe and frequent droughts, which will have major impacts on food security and livelihoods. High temperatures will mean greater withdrawals by plants and humans, which will lead to a reduction in stream flow. As freshwater becomes scarcer through natural and human withdrawal and drought, and as the sea level rises, salt water will move farther upstream, negatively affecting soils and agricultural production.

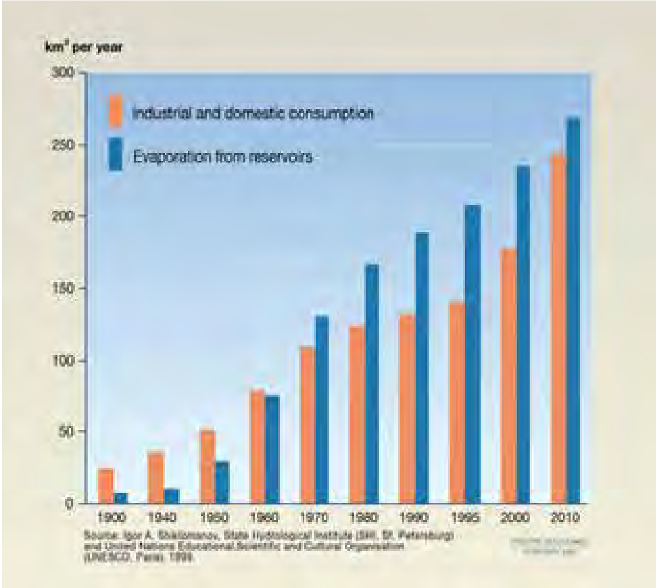


Figure 2: Evaporation from reservoirs compared to amount of water consumed by industry and domestic use. Source: UNESCO, 1999

Changes in evapotranspiration (or the transport of water into the atmosphere from soil, vegetation, and water surfaces) are more difficult to predict. In addition, the amount and/or rate of evaporation from seasonal snowpack and glaciers may be increasing, which means that this water is "lost" to the basin and passes directly to the atmosphere without entering freshwater ecosystems. This will in turn change the amount of runoff.

By 2050, increased water stress will impact land areas twice the size of those areas experiencing increased water availability.

For instance, a 2006 climate study from the University of Cape Town shows that even a small decrease in rainfall in southern Africa could cause a drastic reduction in river flows. The study revealed that a temperature rise of 3-6°C will reduce the water available to southern Africa by as much as half. The authors of the study note that "it will be like erasing large sections of the rivers off the map."[13] Currently, climate activists and practitioners are pushing to keep temperatures below a 2°C rise in recognition of the disastrous existing impacts and potential future consequences of further temperature increases.

Increased evaporation will reduce water storage and electricity generation for all types of dams, but especially those with large, shallow reservoirs. About 170 cubic kilometers of water evaporates from the world's reservoirs every year, more than 7% of the total amount of freshwater consumed by all human activities. To give just one example from a water-stressed country, the annual average of 11.2 cubic kilometers of water evaporated from Egypt's High Aswan Dam reservoir is around 10% of its storage – roughly equal to the total withdrawals of water for residential and commercial use throughout Africa.[14]

HYDROPOWER VULNERABILITY

Hydropower generates almost one-fifth of the world's electricity – though in some nations, nearly all electricity comes from hydropower. Of the world's 50,000 large dams, about 5,000 are strictly for producing hydropower. Brazil, Canada, China, and the United States account for over half of the world's hydropower capacity.

However, climate change means that an over-reliance on hydropower can lead to serious risks to energy security and a nation's economy, since unpredictabil-

Glacial lakes in Bhutan. Photo: NASA

ity in precipitation coupled with extreme weather events will make hydropower an increasingly risky business (see maps, page 19). Energy shortages can impact the delivery of health services, businesses and livelihoods, and education, all of which can in turn decrease a community's resilience to other climate change impacts.

In recent decades, drought has already had a major impact on energy production in many regions where large hydropower dominates. In some places, electricity output was reduced by as much as half. Dozens of developing countries are highly dependent on hydropower, yet it is in these places where the bulk of new large hydro capacity is planned, including Brazil, Ecuador, Ethiopia, China and Southern Africa. For instance, most of the Nile Basin states get more than 70% of their electricity from hydro. The Intergovernmental Panel on Climate Change (IPCC) notes that there has already been "a reduction in run-off of 20% between 1972 and 1987" in the Nile and "significant interruptions in hydropower generation as a result of severe droughts."[15]

These changes illustrate an important concept in hydropower design known as *stationarity,* which is rooted in the idea that future hydrology is predictable

A tangle of electrical wires in Raipur, India. India gets about 20-25% of its electricity from hydropower dams. Hydropower production fell by 19% between 2011 and 2012 due to low rainfall, contributing to one of the world's largest blackouts in 2012. Photo: Phil Putnam

and can be based on past hydrological records, and that water-dependent infrastructure projects can be designed to be reliable. Climate change and human alterations to the hydrological cycle have led to the "death of stationarity" and an end to reliable predictions of future flow regimes. This means that in order to effectively adapt to climate change, we will need innovative approaches to water management that are dynamic and can respond with flexibility to all types of events.

Climate Research Reveals Risks in the Zambezi Basin

Currently, 13,000 megawatts of new large-dam hydro is proposed for the Zambezi River in southern Africa, at a time when the river will experience worse droughts and more extreme floods due to climate change. Dams being proposed and built now will be negatively affected, yet energy planning in the basin is not taking serious steps to address these huge hydrological uncertainties. The result could be dams that are uneconomic, disruptive to the energy sector, and possibly even dangerous.

International Rivers commissioned a hydrologist to analyze the hydrological risks to hydropower dams on the Zambezi River because the region's dam-building agencies had not done so, even though they were moving forward with a number of new dams.

The report, A Risky Climate for Southern African Hydro, revealed that the designs for two of the bigger dam projects proposed for the Zambezi – Batoka Gorge and Mphanda Nkuwa – are based on historical hydrological records and have not been evaluated for the risks associated with reduced flows and more extreme flood and drought cycles. Under future climate scenarios, both dams are unlikely to deliver expected services over their lifetimes. Similarly, they have not been designed for more frequent extreme floods. If dams are "under-designed" for larger floods, the result could be serious safety risks to millions of people living in the basin.

Existing dams on the Zambezi have profoundly altered the hydrological conditions important for maintaining downstream livelihoods and biodiversity. The ecological goods and services provided by the Zambezi, which are key to enabling societies to adapt to climate change, are under grave threat. These services are not being properly valued in planning for large dams in the basin.

The report recommends a series of steps to address the coming storm of hydrological changes, including changes to how dams are planned and operated. Its findings are currently being used by civil society groups in the region.

Download the report here:
www.internationalrivers.org/node/7673

Reservoir Emissions Fuel Climate Change

A growing number of scientific studies indicate that reservoirs, especially in the tropics, are a significant source of global greenhouse gas pollution. Brazilian researchers estimated in 2007 that methane from dams is responsible for around 4% of human-caused climate change. In addition, legal and illegal logging at dam sites to clear the area for inundation also removes important carbon sinks.

Where Do the Emissions Come From?

Dam reservoirs emit greenhouse gases, primarily methane (CH_4) and carbon dioxide (CO_2). Measurements have been taken at dozens of reservoirs, and all were shown to emit such gases. Gases are emitted from the surface of the reservoir, at turbines and spillways, and for tens of kilometers downstream. Emissions are highest in hot climates. Hydro plants in the tropics with large reservoirs relative to their generating capacity can have a much greater impact on global warming than fossil fuel plants generating equivalent amounts of electricity (see Figure 3).

The "fuel" for these emissions is rotting organic matter from the vegetation and soils flooded when the reservoir is first filled. The carbon in the plankton and plants that live and die in the reservoir, the detritus washed down from the watershed above, and the seasonal flooding of plants along the reservoir fringes, all ensure that emissions continue for the lifetime of the reservoir. Emission levels vary widely between different reservoirs depending upon the area and type of ecosystems flooded, reservoir depth and shape, the local climate, and the way in which the dam is operated. For instance, China's reservoirs are often deep but sludge-filled, while Brazil's reservoirs are shallow and in a tropical zone. Both cases can lead to high emissions.

Today, global estimates continue to be variable, partly because almost no information is available for the subtropics and especially from Asia where, according to a Toulouse University study, two-thirds of dams are located. Comprehensive studies to analyze a dam's life-cycle emissions are more important now than ever before, partly because millions of dollars in carbon credits are being sought to support hydropower projects.

In Laos, for instance, the construction of reservoirs and related deforestation has led to the country shifting from being a carbon sink to a net emitter of greenhouse gas emissions (GHGs), according to the EU Global Climate Change Alliance. Preliminary research on reservoir emissions at Nam Theun 2 and a 2011 study on the Nam Ngum and Nam Leuk reservoirs showed them to be significant sources of methane, which is 25 times more potent than carbon dioxide over 100 years. While reservoir emissions studies are limited in Southeast Asia, the study of the Nam Leuk reservoir revealed that "GHG emissions are still significant 10 years after impoundment" and that the emissions values were comparable to other tropical reservoirs such as those in Brazil, whose reservoirs have been studied the most.

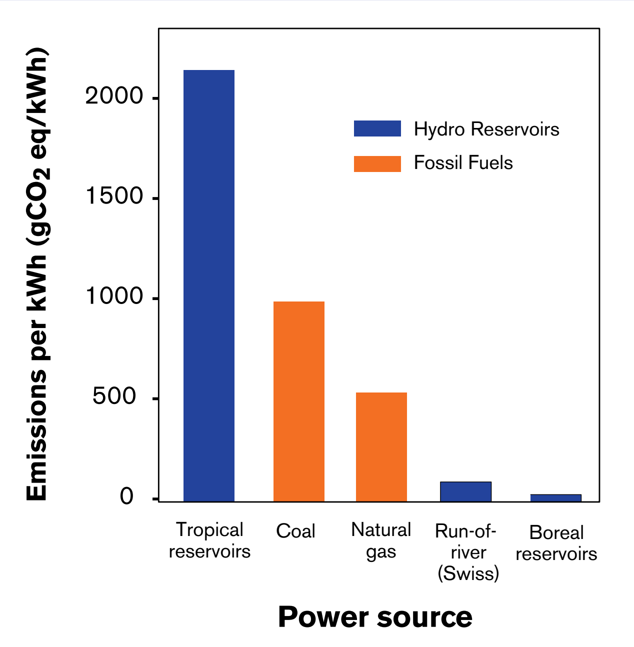


Figure 3: Comparison of emissions per kilowatt-hour for various power sources. The tropical reservoir bar represents the "reservoir net" average emissions from three Brazilian reservoirs. The boreal reservoir bar represents the gross average emissions from five Canadian reservoirs. Run-of-River bar refers to the Wohlensee reservoir in Switzerland. Source: "Dirty Hydro: Dams and Greenhouse Gas Emissions," 2008, International Rivers

All new dam designs nowadays need a thorough GHG emissions assessment. Developers should choose low emissions designs. Dams likely to emit as much GHG as a conventional fossil fuel plant should not be developed. Biomass in the reservoir should be removed before filling. More than 27 European nations and Australia, and many cities and states (for example, Vancouver, Canada) now mandate a charge for GHG emissions. A hydropower project must internalize its reservoir emissions in project design and cost/benefit analysis. The World Bank and other global institutions need to create a global agreement for the "Polluter Pays Principle," or a GHG emissions tax.

For more information, see:
www.internationalrivers.org/node/2374

Maps of Climate Risks & Dams

Around the world, climate change is melting snowpack and glaciers that feed major rivers, contributing to drought-caused hydroelectricity blackouts, and threatening the water supply and river resources of billions of people. Major rivers worldwide have experienced dramatic changes in flow due to dams decreasing their natural ability to adjust to disturbances. For a regularly updated online version of this map, see: www.internationalrivers.org/node/3502

Even the most optimistic climate models for the second half of this century suggest that 30-70% of **California's** *Sierra Nevada snowpack will disappear. California's 1,000 dams will face the twin challenges of excessive high flows, which could make them potential hazards to millions living below them; and diminishing flows from increasing drought.*

Climate scientists at Oregon State University project a 56% drop in water stored in peak snowpack in Oregon's **McKenzie River** *watershed by mid-century. The water drop will affect hydropower, agriculture, ecosystems and industry. More than 70% of Oregon's population lives in the watershed.*

A study by Queen's University reveals that the **Winnipeg River Basin** *could be hit by severe droughts in a climate-changed world. This could set back hydropower generation for Manitoba Hydro, which operates six dams on the river.*

Climate scientists predict 15% less water in the **Colorado River Basin** *by mid-century, at the same time the basin is expected to see its population increase by a third or more. The river is already over-allocated among seven US states and Mexico, and a long drought left the two biggest reservoirs at Hoover and Glen Canyon dams only half full, causing tensions among competing users. The Colorado Delta in Mexico is sinking as a result of decreased sediment delivery, which increases risk from storms.*

Costa Rica *gets about 80% of its electricity from hydropower, and 10% of the nation's power comes from one large dam (Angostura). Power shortages have been increasing since the rainy season started to come later and with less rain. The nation intends to build more hydropower plants, but also hopes to diversify the energy sector, including more wind, solar and geothermal.*

Hydropower supported by **Andean** *glaciers supplies 81% of Peru's electricity, 73% of Colombia's, 72% of Ecuador's, and 50% of Bolivia's. A recent study predicts significant economic losses from climate-induced glacial retreat.*

Brazil's *hydro-dependent energy sector is at grave risk of climate change, according to the study "The Vulnerability of Energy Systems to Climate Change." The study found that by 2040, Brazil will see significant reductions in hydropower production as a result of a dryer climate, and will need to invest US$503 billion to counter these impacts.*

About 20% of Europe's electricity comes from hydropower. However, the generating potential of hydropower plants is projected to decrease by 6% by the 2070s. Glacial melt from the **Alps** *has been increasing in the past half-century, which means countries like Switzerland that rely on steady glacial runoff for hydropower will see a major strain on electricity production in the long-run if better alternatives are not found.*

Drought lowered hydropower output in **Romania and Bosnia** *in 2012. Production in Bosnia was 42% below target, according to media reports. Bosnia produces about 40% of its energy from hydropower, and normally exports power to neighbors. In recent years, the region has been hit with multiple life-threatening floods.*

West Africa's **Volta River Basin** *is expected to suffer severe declines in water availability in coming years, which could deprive millions of people of food and hydropower, according to a study by the International Water Management Institute. By 2050 current hydropower production could be cut in half, the study found.*

The waters of the **Blue Nile** *are critical to millions of mostly poor people in Egypt, the Sudans, and Ethiopia. Increasing water extraction, damming in Ethiopia and the effects of climate change could significantly reduce water flowing into Egypt, raising tensions over the shared river. Runoff is expected to decrease even if precipitation increases, due to increased evaporation from higher temperatures, affecting both hydropower generation and irrigated agriculture. Experts believe the losses in hydropower alone will cost millions of dollars per year.*

Kenya *has historically been highly dependent on hydropower for its electricity. After withering droughts led to blackouts in 2009-2011, the government began to develop its huge reserves of geothermal energy. Kenya is now Africa's leading user of geothermal, and has begun to exploit wind power as well.*

Tanzania's *hydropower dams have been running on empty in recent years, causing power shortages and blackouts, and bringing unexpected costs for emergency power plants. The East African nation has developed a world-class environmental flows program for the some of its major river basins, as part of a growing focus on climate adaptation.*

Researchers predict that a 3-6°C increase in temperature in the next few years will result in a 30-50% reduction in water availability in **Southern Africa**, *a 15-35% reduction in agriculture production across Africa, and 300 million more people at risk of coastal flooding each year. The World Bank says even a 2°C increase could mean that Africa could see permanent reductions in per capita water consumption of 4-5% per year.*

Most glaciers on the **Tibetan plateau** *are retreating rapidly, according to a 2012 study based on 30 years of measurements of more than 7,000 glaciers. Seasonal snowpack is in widespread decline with warmer winters (more rain and less snow) and earlier melt dates. Rivers originating in the Tibetan plateau provide water for millions living downstream. China is tapping Tibet's rivers for hydropower and water – controversial plans that are of even greater concern in a time of unpredictable flows.* **China's** *three major deltas, the Yellow, the Yangtze, and the Pearl, are all in the world's top 11 highest risk deltas as a result of rising sea levels and a reduction of sediments due to extensive dam building.*

The **Himalayas'** *rapidly melting glaciers and reduced snowpack threaten to reduce water flowing into the Indus, Ganges, and Brahmaputra rivers, which support half a billion people. Hundreds of new hydropower dams are proposed in the Himalayas, with little attention being paid to the climate risks. Thankfully, a new three-year study by the International Centre for Integrated Mountain Development (ICIMOD) began in 2013, in order to assess the current state of the Hindu Kush Himalayas, and to make recommendations on how best to safeguard and develop it.*

Pakistan's **Indus River**, *which flows from the Himalayas, is expected to see reduced flows of up to 40% by 2050 due to reduced snowfall and glacial melting. A cycle of heavy monsoons and worse droughts is also predicted, which will adversely affect food security.*

Bangladesh's *location on a low-lying delta with a very high population density makes it one of the countries most at risk of climate change. Dams that hold back water and sediment in the upper reaches of the Ganges-Brahmaputra-Meghna basins increase Bangladesh's risk of waterlogging and flooding. Rising sea levels and increasing risk from large floods have interrupted agriculture and challenged water resources, health, and energy supply, not to mention risking lives and creating legions of climate refugees each year.*

Changes to **India's monsoon** *are expected to trigger more extreme storms that will jeopardize the economics and safety of hydropower dams, as well as billions of lives. Sinking deltas from dams that hold back sediment also increase the risk of flooding in the region. Recent analysis reveals that India's large dams are responsible for 19% of the country's total global warming impact,*[16] *making them the region's largest global warming contributor.*

Vietnam's low-lying **Mekong Delta** *is one of the world's most vulnerable to climate change. Rising sea levels, growing water shortages, and increasing saltwater intrusion all threaten the delta's abundant agriculture and fisheries, and a fifth of Vietnam's population. Plans for extensive dam development upstream on the Mekong could block sediment loads that nourish the delta's soils and rebuild land lost to coastal erosion and natural subsidence.*

Australia's *two largest rivers, the Murray and the Darling, have been extensively dammed and dewatered, reducing average flows by nearly three-quarters. The desiccation of the river system has seen extensive loss of floodplain forests and impacts on pastoralists, fisheries and tourism. The river system is increasingly saline, endangering the water supply for over two million people. The Murray-Darling Basin's location is believed to be particularly vulnerable to climate change-induced drying. The Australian government has an AU$14.7 billion Basin Plan to return up to 30% of the previously diverted water to the rivers, but this may not be enough, especially if the climate dries further.*

The Xayaburi Dam, if built, will block critical fish migration routes for dozens of fish species, as well as sediment flows in the Mekong River, affecting the agriculture and fisheries as far downstream as the Mekong Delta in Vietnam. Photo: International Rivers

Assessing Climate Risks to Communities

While large dams and diversion projects are often touted as appropriate adaptation projects to deal with flooding, water shortages or storage, not only can these projects be highly vulnerable to climate change themselves, but they can also compound the impacts of climate change and threaten the climate resilience of vulnerable populations. Many of these projects will likely have severe impacts on water quality and quantity, which will in turn have negative consequences for communities' adaptive capacity. Large dams may also lead to serious regional security issues, especially in the case of transboundary rivers.

In order to prevent a particular adaptation project from having harmful impacts (known as "maladaptation"), it is critical that it be assessed for its climate change risks *and* for its impact on the adaptation of local communities. Given the considerable uncertainties around climate change impacts on human and natural systems, many adaptation practitioners recommend taking a risk-based approach to assessing a range of possible scenarios and the ecosystems or populations that will be most vulnerable to change, rather than an impact assessment approach that relies on predictions of what might happen.

These vulnerability and risk assessments can and should be done in a range of planning activities, but urging governments to require them at the Strategic Environmental Assessment (SEA) phase of water and energy planning should be a minimum. (SEAs are not always done, so pushing for this kind of assessment is a good first step.) In addition, they should always be done in consultation with local communities and regional experts in order to ensure that you have the most relevant and accurate data to work with before you begin assessing a development project for its climate risks or developing your own adaptation project (see Chapters 4 and 5).

This chapter discusses the types of assessments that you can conduct with your communities, and the challenges you might encounter along the way.

COMMUNITY-BASED ADAPTATION

Providing people with tools for conducting comprehensive assessments of local vulnerabilities to climate impacts and helping them prioritize responses to those impacts will improve their capacity to adapt. It is important to obtain information from community members about local adaptation and coping strategies that already exist, so that further activities and assessments can be done in a way that meets community goals and preserves community traditions.[17] Working with community representatives and developers to design and implement inclusive processes for soliciting this type of information is critical for ensuring that local needs are well identified and prioritized in assessment processes.

Before pursuing community-based assessments of any type, it is important to first think about what kinds of information you might need, how credible that information is, and if you are likely to have a gap between what the community wants and what you can deliver (especially when it comes to accurate climate data). It is also critical to determine how durable your decisions will likely be and how much they might lock you into one particular pathway. According to John Matthews, Director of Freshwater Climate Change at Conservation International, "This is a fundamentally different way of managing resources and infrastructure compared to what adaptation practitioners have been doing."

Women demonstrate an improved cooking stove in a Darfur refugee camp. Photo: Potential Energy

Climate change adaptation is a process rather than a single event. Uncertainty, vulnerability and risk should be regularly re-evaluated. Assessments are not carved in stone and will need to be revised. A decision-making process that is transparent, holistic and participatory will more likely lead to accurate assessment and sustainable solutions.

> "The expectation that you can make decisions that will remain useful and relevant for 100, 50, or even 10 years is probably wrong. You need to make vulnerability assessment an integral component to your work. That might mean, for instance, that you build a smaller water treatment facility or one that is capable of operating over a wider range of conditions or that can be expanded over time."
>
> – John Matthews, Director of Freshwater Climate Change, Conservation International

In addition, the high levels of uncertainty inherent in climate change adaptation means that building in flexibility is the best possible response until uncertainty has been reduced. For instance, if water resources appear to be declining relative to demand, reducing demand through increased efficiency may be a more flexible route than constructing a new dam.[18] For more on improving the climate resilience of decision-making process, see recommendations in Chapter 4.

KEY RECOMMENDATIONS FOR CIVIL SOCIETY GROUPS

Conduct a Community-level Needs Assessment

Setting the context and understanding the key needs of communities – especially the poorest and most vulnerable members – is critical before assessing particular risks and possible solutions. Some of the key activities during this step include:

- Describing the community's livelihood activities, key actors, gender and diversity aspects, and the ecological context.

- Identifying and mapping out the resources that are important to local livelihoods and who has access and control over them.
- Using a needs assessment to identify the social groups that tend to be more marginalized or lack access and control over key resources, and therefore who could be more vulnerable to climate risks.
- Documenting every step of the assessment process.

Detailed field guides on conducting both a needs assessment and capacity assessments can be found here: www.timmagee.net/field-guide-to-cba.

Help Build Capacity

A key role that civil society groups can play is providing community members with information that improves their understanding of climate impacts and strengthens their understanding of and ability to document local climate change impacts. This will allow them to more easily identify the climate risks that affect them.[19] Information can range from the more technical (for example, training people in citizen science practices so they can document how changing climate patterns are affecting them locally), to the basic (for example, providing affected communities with a greater understanding of what general climate change impacts are projected for their region). If people living in river basins can deepen their understanding of climate change impacts and vulnerabilities, they can better position themselves to provide strong and persuasive input in decision-making processes surrounding development projects.

In 2011, villagers mapped fishing grounds, riverbank farmland, river morphology and sub-ecosystems for the Mekong River. Photo: TERRA

Civil society groups can develop local resources to enhance community understanding of the ways that climate change will impact ecosystems and livelihoods. These activities should include:

- Conducting research using academic journals and other reliable sources to define the local climate change problem.
- Meeting with local experts who have experience in the areas of climate change or in adaptation in your region. This person could be someone from a government weather office or a climate specialist at an NGO or local university.
- Document changes you are already seeing through maps and photos.

HOW IS ADAPTATION DIFFERENT FROM COPING?

The terms "adaptation" and "coping" are somtimes used interchangeably, leading to confusion about the similarities and differences between these two important concepts. The following lists of characteristics are a compilation of brainstorming sessions by groups of development practitioners in Ghana, Niger and Nepal.

COPING	ADAPTATION
Short-term and immediate	Oriented towards longer term livelihoods security
Oriented towards survival	A continuous process
Not continuous	Results are sustained
Motivated by crisis, reactive	Uses resources efficiently and sustainably
Often degrades resource base	Involves planning
Prompted by a lack of alternatives	Combines old and new strategies and knowledge
	Focused on finding alternatives

Figure 4: Coping with climate change vs. adapting to it. Source: "Climate Vulnerability and Capacity Analysis Handbook" © 2009 by CARE International. Used with permission.

Empower Women in the Community

Women in developing countries face disproportionately high risks to their livelihoods and health from climate change. Adaptation projects that address their needs, such as rainwater harvesting structures and clean stoves, can begin to improve women's livelihoods and their ability to support their families.[20] Further efforts to develop and sustain education and income generation opportunities for women can increase community resilience to future climate risks. Engaging and empowering women from the early assessment stage all the way through the adaptation project development phase is critical. Civil society groups should encourage women to actively participate in local development schemes, decision-making, and entrepreneurship, particularly through women's mentoring groups. As noted by UNEP Executive Director Achim Steiner, "Women often play a stronger role than men in the management of ecosystem services and food security. Hence, sustainable adaptation must focus on gender and the role of women if it is to become successful."

Women have long taken action to protect rivers. These women were speaking out against the Sardar Sarovar Dam in India. Photo: Karen Robinson

Identify the Risks and Vulnerabilities

Once a local community and supporting NGOs have gathered both local knowledge and scientific information on climate change impacts, combine them to develop a picture of the climate risks and vulnerabilities of the local community. One approach to this is conducting a vulnerability and risk assessment, which is the process of evaluating the risks associated with a particular hazard on a certain group of people, and their level of vulnerability. As part of the process, it is important to also identify the gaps in information and provide support to community members to document immediate climate change impacts in order to fill in these gaps (see "Climate Modeling for Adaptation and Freshwater Management" on page 27 for how to deal with uncertainty). In particular, if the riverine community is already being negatively impacted by water and energy infrastructure projects such as large dams, support them in documenting the impacts of dam operation on their livelihoods and in identifying projects that can meet their needs in a resilient way. See *Appendix 1: Key Resources* for adaptation NGOs with experience in this area that you can contact.

Risk-based approaches typically involve (1) defining objectives and identifying the components of interest/ concern, (2) establishing the impact and likelihood of events that could compromise those objectives, (3) identifying the options that reduce the risk of the identified events, and (4) assessing adaptation options to determine suitability and timing of intervention.[21] Identification of where ecosystems are likely to be most sensitive to changes in climate should be an integral part of a vulnerability and risk assessment. Some examples of how to do this are:

- Mark on a calendar when key seasonal events (wet and dry season), hazards (flooding, diseases), and special events (such as planting and harvesting) occur;
- Assess if the region falls in a high-risk zone (for example, from glacial melting, upstream GLOF risk, landslide and flash flood risks);
- Make this information available to all community members; and
- Begin designing specific strategies to address specific climate-related problems revealed by the vulnerability assessment (for more, see Chapter 4).

Maps are a very useful tool for sharing and documenting all kinds of information that can be used for creating needs assessments, showing patterns of climate change on a local community, mapping key resources and their role in livelihoods, and much more. A guide on making community maps for advocacy work can be found here: www.internationalrivers.org/node/4000

Combine Top-down with Bottom-up Approaches

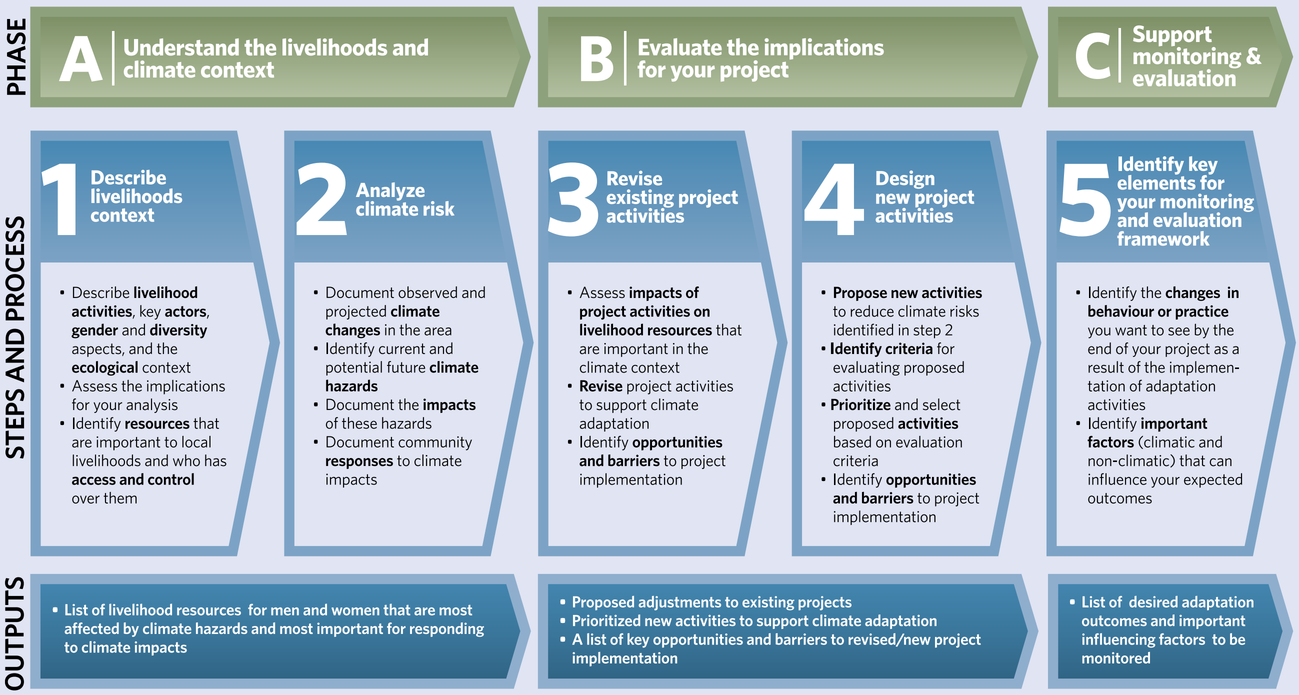
Top-down approaches to risk assessment attempt to characterize the broad likelihood of harmful impacts through the generation of models that analyze future climatic change on a large area (say, at the scale of a country or entire watershed). Bottom-up approaches involve investigating the exposure, sensitivity, and adaptive capacity of a particular system or community. Both can be useful – especially when their findings are used to inform each other. Civil society groups can partner with academic institutions or government agencies that have access to climate modeling tools. However, there are certain limitations to top-down approaches that make them a lower priority when resources are limited (see "Climate Modeling for Adaptation and Freshwater Management" on page 27).

Tools for Climate Adaptation and Risk Management in the Water Sector

While tools are not in themselves the solution, they can support the decision-making process if they are used to answer specific and well-formulated questions. A number of tools exist for conducting community-level assessments and developing adaptation projects. Below are some key things to keep in mind, as recommended by Julian Doczi, Research Officer at the Overseas Development Institute's Water Policy Programme:

- Think carefully about your specific needs. In the 'tool industry,' each developer wants to 'sell' you their tool, like any other product.
- Do your research, and don't rush to select the first tool you discover – it might not be best suited for your needs and could even increase your risk of maladaptation.
- When choosing, consider:
  - Relevance for your context, language, audience, etc.
  - What type of tool(s) do you need?
  - Complexity (will you need training?)
  - Price?
  - User support available? (Is it kept updated?)
  - Do you need a tool at all?
- No tool is perfect – you might need to use several.

Below is one example of a tool that focuses on community-based risk screening, the CRiSTAL Framework. CRiSTAL is a community-based risk screening tool that focuses on adaptation and livelihoods. Learn more: www.iisd.org/cristaltool.



ASSESSING THE CLIMATE RISKS OF PLANNED AND EXISTING PROJECTS

For communities facing planned or existing large water and energy projects, asking the right questions of development planners and government decision-makers can help guide them in evaluating the potential climate risks and the possible impact a project will have on a community's climate resilience. Asking these questions can also prompt decision-makers to develop a climate risk assessment, and potentially reconsider or revise project plans. These questions should be raised when evaluating a river basin plan, Strategic Environmental Assessment (SEA), feasibility study, or a Social and Environmental

Climate Modeling for Adaptation and Freshwater Management

The same methodologies that created mismatched infrastructure and institutions in the developed world are now being used in the developing world for a second "golden age" of rapid water infrastructure expansion. Poor investments made now in Africa, Asia, and South America are likely to plague if not undermine economies and ecosystems and lay the seeds for conflict, inequity, and environmental degradation for future generations. These issues are urgent and important. Decisions about long-term water management are made every day in every nation, and many of these decisions are not resilient.

Effective expertise has been coalescing in many fields in the past decade. We need a synthesis of best-practice water resources management that can inform resilient and strategic decisions and actions, while also functioning in a reliable manner in the developing world, where data and governance limitations often present barriers. Below are some highlights of recent strategies, and their strengths and limitations for water resource management:

Decision Scaling

General Circulation Models (GCMs), or global climate models, have emerged as a widespread tool for projecting future climate and water resource states. However, these models were not designed for adaptation purposes and their quantitative nature can often hide important uncertainties. Thus, they should only be partially used to inform decisions on climate adaptation. Instead, "decision scaling" approaches are bottom-up approaches that take important local characteristics and capacities into account before adaptation solutions are tested against climate projections. Ideally both top-down approaches that include scaling down climate models to the local level and bottom-up approaches should be used together to guide decision-making.

What Do Climate Models Show?

Climate models can with some accuracy simulate changes in observed air temperature, ocean heat content and some regular events like El Niño. They cannot simulate changes in the water cycle such as precipitation, shifts in extreme events (such as frequency or severity of droughts and floods or tropical cyclones), form of precipitation (rain vs. snow), and evapotranspiration. When applied with other models such as runoff or flow models, uncertainties can increase. Due to these limitations, climate models are better at setting the context rather than informing decisions. They are also useful when used together with other types of data, such as historic records and paleoclimate data. This would mean planning for multiple futures and focusing on having a good process of decision-making, rather than trying to make accurate predictions through different climate and hydrological models.

Understanding Modes of Change

There are broadly three major types of climate change impacts on a system that can be expected. While these changes can be difficult to predict, identifying them as best as possible is important, since they will have severe impacts on natural and human systems.[22] In *linear* change, variables such as air temperature, mean precipitation, or even mean monthly extreme precipitation may shift in a relatively even way in some regions. However, changes in freshwater systems are more likely to exhibit a different kind of change, that of the *degree and frequency* of extreme events and in seasonality. Finally, *state-level* change is the shift of climate from a period of relative stability to a period of rapid shifts (passing a climate tipping point or "threshold"), followed by another period of relative stability but in a new state. An example of this last change is the rapid disappearance of glaciers in Glacier National Park in the US, where glaciers have given way to snowpack, then tundra, then grasslands and forest.

What Are New Approaches to Deal with Uncertainty?

Consideration of future impacts of climate change cannot be based simply on taking global climate models and scaling them down to the local level ("downscaling"); instead it requires an assessment of ecosystem sensitivities and a variety of possible futures. Conducting a vulnerability assessment adopts a broader and more cross-sectoral view, without reliance on the accuracy of these models. For practitioners with limited financial and technical resources, a bottom-up approach to adaptation is to use the "tipping point" concept, which attempts to determine how much a system or community can cope with climate change before impacts become unacceptable. This can include mapping out unwanted, high-risk scenarios, so that actions can be taken now to avoid as much as possible the costly consequences of climate change. Such actions could include implementing measures to deal with identified risks, preparing a response plan to potential future risks, and developing "signposts" in a monitoring plan that can identify emerging changes.

For more information, visit: www.alliance4water.org

Adapted from "Caveat Adaptor: The Best Use of Climate Model Simulations for Climate Adaptation and Freshwater Management," White Paper 1, Alliance for Global Water Adaptation (AGWA), 2013, Washington, DC.

Impact Assessment (SEIA). Below are some key questions that civil society can ask regarding these projects. A full list of questions can be found in Appendix 3.

Social Impacts

Water resource availability:

- How will the project affect the community's access to clean water? What will be the impact on existing sources, including groundwater? Will new sources be provided if existing sources will be compromised?
- Does the project take a "catchment approach" and analyze cumulative impacts of all dams in the basin?
- Are there flood safety measures or drought risk management plans in place?
- Do relocation sites have sufficient access to natural resources?
- Are there adaptive management plans for high and low precipitation scenarios?

Livelihoods:

- How are livelihoods or loss of livelihoods considered in the development of the project, and is the analysis comprehensive – are direct and indirect impacts considered? (These might include impacts caused by large migratory work force, changes to fisheries and forests, a change in access to the river or to neighboring communities, etc.)
- Have the main effects of climate change on the community been assessed and addressed in the project's social impact assessment?

Health:

- Has a health impact study been done? Have local public health agencies been involved? Have the health impacts of a large migratory construction crew (such as sexually transmitted diseases) on the local population been addressed?
- What health services will be provided to deal with any health impacts from the project? How are these services being paid for?
- What types of strategies are being proposed or implement to avoid or mitigate waterborne diseases?

Governance:

- Have strong local paths of engagement been incorporated in government-led assessments and mitigation processes?
- Is there a disaster risk management plan and preventive measures in place to deal with droughts and floods?
- Is there an adaptation plan in place to help mitigate the negative impacts of dams on communities under different scenarios?
- Are accountability mechanisms in place? Is there a means of enforcement to hold developers accountable for meeting projected water and energy needs? Are there accountability mechanisms for developer-led damage to key environmental services?

Environmental Impacts

Soil erosion in watersheds and coastal deltas:

- Does the river basin experience high precipitation and is precipitation expected to increase? Higher precipitation will mean greater erosion. What is the current extent of erosion in the watershed?
- How will sedimentation be managed at the proposed or existing dams?
- What rehabilitation or watershed management projects (such as afforestation or improved farming practices) have been proposed in the watershed? What are their costs and have they been accounted for in project assessments?
- Have the impacts of the loss of sediment transport on downstream ecosystems and floodplain agriculture been analyzed and addressed?

River flows:

- How will climate change affect a river's natural flow? Will it increase or decrease magnitude, duration, timing, and frequency? How have precipitation and flow changes expected from climate change been addressed?

Community researchers were involved in a long citizen science project to in Thailand to assess Pak Mun Dam's impacts. Photo: Living River Siam

- How will the project change the river's natural flow and how will this alter or disrupt surrounding river vegetation, floodplain agriculture, and fisheries?
- What will be the economic impact of these losses as a result of altered flows? Are these costs fully accounted for in the cost-benefit analysis for new river infrastructure?
- What is the plan for calculating and incorporating environmental flows into the design and operation of a project? Are there plans to bring environmental flows into the operation of existing projects?
- What role will local communities be allowed to play in the maintenance and refinement of the environmental flows plan? Are there transparent mechanisms for monitoring that the public can use?
- How will the environmental flows plan be enforced?

Deforestation:

- Does the project account for the greenhouse gas emissions from deforestation?
- In the case of a project constructed as a low-carbon energy option, will deforestation turn the project into a net carbon emitter? Does this disqualify the project from receiving clean energy or mitigation funding?
- What impacts will climate change and deforestation have on local livelihoods and resource availability? What measures are in place to address these impacts?

Greenhouse gas emissions:

- Are emissions being accounted for in the full life cycle of the project, including construction, deforestation, and materials used?
- For dams, are all possible sources of emissions accounted for as part of the GHG measurements?

Economic and Safety Impacts

Economic feasibility:

- Does the project have a disaster risk management plan and is it funded? Which government agency will be responsible for it?

Dam reservoirs, especially in the tropics, are a significant source of global greenhouse gas pollution. Photo: Frédéric Guérin

- Are the costs of climate-change impacts on project operation (such as water shortages during times of drought) incorporated into overall project costs?
- Have the costs of dam decommissioning been incorporated into project cost assessments?
- Before new projects are planned, have existing projects been assessed for reoperation or rehabilitation?

Electrical output:

- Does the project's economic analysis take into account climate change scenarios?
- What alternative back-up energy systems exist in-country if an energy project is not generating power?

Structural integrity and dam safety:

- Are different climate change scenarios considered in project safety assessments and the design of the dam?
- Are there national and community-level evacuation plans and emergency notification systems in place in case of a dam failure due to floods?

Rainwater harvesting is becoming a critical life-support system for rural dwellers in Ethiopia. Photo: RAIN

Addressing Climate Risks to Communities

While many large dam projects purport to enhance climate resilience, in reality, many of them threaten to decrease climate resilience, especially for the rural poor. In the case of large multipurpose dams, for instance, there are often built-in incompatibilities between generation of electricity and provision of water supply during the dry season, when water delivery is most needed. When dam operators must choose one over the other, electricity generation is almost always prioritized over water supply. Hydropower dams, if poorly operated, can also diminish or eliminate seasonal flood pulses downstream, reducing the productivity and extent of floodplain and riverbank agricultural systems, an important alternative to drought-prone rain-fed cropping practices throughout the world. Evaporation from large reservoirs further decreases water availability for downstream use.

In order to avoid undermining climate adaptation activities and a community's ability to respond to climate change, integrated river basin management should be practiced, and projects that will help vulnerable groups prepare for, withstand and recover from negative climate change impacts should be prioritized. Resilience strategies should be an integral part of research, development, planning, training, capacity building, and operation of major river development projects.

This chapter describes some of the methods of avoiding maladaptation projects, and how to address existing or future climate risks.

KEY RECOMMENDATIONS FOR CIVIL SOCIETY GROUPS

Conduct or Participate in an Options Assessment

In most cases, good alternatives to large water infrastructure projects exist. The World Commission on Dams (WCD) recommended a process to ensure development projects meet local needs while doing the least harm. To explore these alternatives, needs for water, food and energy must be assessed and objectives clearly defined. Selection of the most appropriate development response is based on a comprehensive and participatory assessment of the full range of policy, institutional and technical options. In the assessment process, social and environmental aspects are given the same significance as economic and financial factors. The options assessment process continues through all stages of planning, project development and operations.

Evaluation of options for regional energy strategies should incorporate climate assessments that measure the potential of each option to produce negative outcomes, and should rigorously address the potential for projects to lead to maladaptation or will undermine existing adaptation efforts. For regions that are both slated for new dam projects and home to existing projects, exploring opportunities for retrofitting existing dams as an alternative to constructing new infrastructure should be considered in the project selection stage.

Prioritize Integrated Planning and Policy

Civil society groups can develop small-scale integrated river-basin projects that help promote climate resilience by helping vulnerable groups prepare for, withstand and recover from the negative effects of climate change. An integrated project, for instance, could be a micro-hydro project whose water is augmented by extensive watershed protection, and which recycles water coming out from the turbines to be used on croplands.

Since climate change also adds additional risk to electricity resources planning, Integrated Resource Plans (IRP) should be used to evaluate and rank all options for delivering utility services, including all end-use efficiency and distributed generation approaches, and according to comprehensive cost-benefit analyses.

At the national level, civil society groups can push for more integrated policies that help with accomplishing multiple objectives, such as climate change adaptation and rural development and poverty alleviation. For example, the Mahatma Gandhi Rural Employment Guarantee Act (MGNREGA) in India links traditional development projects with climate adaptation work through the development of decentralized renewable energy projects. Many community members participate because they receive wages, while also growing their climate awareness.

Promote the Precautionary Principle

Civil society groups should encourage decision-makers to explicitly adopt the precautionary principle when planning new projects that might have a large environmental and/or social impact. The precautionary principle is defined as: "Where an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically. In this context, the proponent of an activity, rather than the public, should bear the burden of proof."[23] Four key components of this principle can be summarized as:

- Taking preventive action in the face of uncertainty.
- Shifting the burden of proof to the proponents of an activity. In other words, the burden of proof should rest with those who *propose* rather than those who *oppose* a particular project.
- Exploring a wide range of alternatives to possibly harmful actions.
- Increasing public participation in decision-making.

Due to the high uncertainty of climate change, this means decision-makers should move away from making projections based on best-case historical data. While moving towards a risk-based analysis framework is a positive first step, a precautionary approach moves beyond this because it accounts for more uncertainty in a changing climate.

Protect Ecosystem Services and Environmental Flows

Measures to protect ecosystem services and implement environmental flows allow river ecosystems to have enough capacity to absorb climate stressors. Comprehensive basin-wide planning should thus consider a full accounting of the values of ecosystem services supported by river flows. Community- and ecosystem-based adaptation approaches that link

Populations of freshwater species declined by 50% between 1970 and 2000.

biodiversity and ecosystem services with poverty alleviation and building community resilience to climate change must be central to any comprehensive planning efforts.[24]

Below are some examples of incorporating ecosystem service management in climate adaptation (adapted from a UNEP study):[25]

- *Recognize the multiple functions and services provided by ecosystems at all levels.* In the context of rivers, this could mean identifying all the key benefits and services that the river provides across different sectors and at both the localized, basin-wide, and – for transboundary rivers – international levels.

- *Reduce pressures on ecosystems.* For rivers, this could include reducing extractive water demands from surface and groundwater, restoring more natural river flows so that freshwater ecosystems are not vulnerable to small, climate-induced changes in runoff, and reducing other pressures such as pollution and overfishing.

- *Link ecosystems-based risk reduction with sustainable livelihoods and development*. For rivers, this could mean, for example, making the connection between income generation from fisheries and regional food security, and how an economically thriving fishery protects the region from the climate-related threats to other food sources.

- *Address risks associated with climate change and extreme events and reduce their impact on ecosystem services.* Climate change will affect the ecosystem services of rivers, for instance by reducing rainfall and thus diminishing river flow. Adaptation solutions that allow communities and local governments to address this risk while also protecting river resources, such as building small check dams to restore groundwater or restoring floodplains, can offer a more sustainable and secure approach to maintaining livelihoods.

- *Involve local stakeholders in decision-making.* This recommendation is a common theme and an underlying principle for any successful climate adaptation project.

260 river basins are shared by two or more countries.

Develop Ecosystem, Livelihood and Disaster Monitoring Systems

Accurate and timely monitoring and detection of shifts in key variables in water quality, quantity and timing are not perfect means to capture emerging trends, but they can track gradual shifts and, ideally, help anticipate tipping points.[28] Such systems need not be expensive and can be decentralized and community-led through the practice of citizen science. However, they should be standardized across the region as much as possible. Civil society groups should also affiliate themselves with an academic and/or government institution that is capable of analyzing the trends and explaining those trends to the community.

Community-level early disaster warning and evacuation plans can help river basin communities become more resilient to extreme climate variability. They can also reduce costs to governments that would otherwise have to provide relief support for the devastation brought about by extreme droughts and floods.

Opening the sluice gate on a small hydro project in Africa. Photo: Wim Klunne

Environmental Flows for Climate Adaptation

California's dammed Trinity River is now flowing more naturally, thanks to an agreement to restore environmental flows. Photo: © Conservation Lands Foundation

The most obvious change in a dammed river is the change to its flow. "Environmental flows" is a system for managing the quantity, timing and quality of water flows below a dam, with the goal of sustaining ecosystems and the human livelihoods that depend on them.[26] Environmental flows are now seen as a critical means of alleviating poverty and creating a more sustainable development path in the developing world. The scale of environmental flows is shifting, from single dams being operated in isolation to networks and portfolios of water infrastructure, managing flow regime at the basin or sub-basin levels.

Having an environmental flows plan for existing and proposed dams is especially important in a changing climate. Many dams around the world presently lack the institutional support and mechanisms needed to control water discharge for environmental flows. Pressing for national laws and regulations to require planning and implementation of environmental flows for all dams would be a good first step.

The most ecologically important aspects of a river's flow are extreme low flows, low flows, high flow pulses, small floods, and large floods. Environmental flows can be designed to restore any of these, with the goal of improving water quality, restoring sediment deposition, addressing the life-cycle needs of fish and wildlife, and restoring the livelihoods of river-based communities.[27]

Before developing an environmental flows plan, it is important to consider what the goal of these flows will be. A variety of objectives can be addressed through environmental flow management, including:

- Dam safety: Manage releases to avoid the reservoir reaching unsafe levels
- Health impacts: Manage releases to reduce the incidence of water-borne diseases
- Flood management: Avoid loss of life and reduce socio-economic impacts
- Environmental management: Provide quantity and quality of water required to maintain ecosystems and enable them to provide sustainable services and good quality water
- Dry season floodplain agriculture: Accommodate harvest period in release management, and
- Water supply: Set priorities based on economic or social considerations, including poverty alleviation

Future structures should be designed from the beginning to ensure compatibility with environmental flows releases, including adequate outflow capacity to realize a range of target outflows, multi-level intakes to allow for water releases corresponding to a range of reservoir storage levels and to improve downstream water quality, and effective passage to enable movement of sediments around dam walls. Many existing dams should be retrofitted to achieve these outcomes. (Note: fish passages are very difficult to get right, and tropical species do not generally do well with such structures.)

Challenges to Implementation

While environmental flows is an important management tool for restoring river systems and the services they provide, getting it right usually requires strong support from a variety of agencies. Many governments and river-management agencies around the world have developed environmental flows policies, yet implementation of these policies remains weak.

At the highest level, political support for environmental flows policy is essential for setting strategic direction, securing resources, working with stakeholders and enforcing the policy.

Having sufficient capabilities within the managing agencies is equally key to success. Conducting a thorough assessment and developing operational rules for environmental flows at even a single dam requires significant technical and institutional capacity. A comprehensive framework for implementation requires that relevant laws, policies and institutions be in place across a wide range of water resource management functions.

Conflicts of interest can waylay the best plans. Environmental flows may involve agencies that plan and manage hydropower, agriculture, land use, industrial development and natural resources. Conflicts of interest will intensify on transboundary rivers without a participatory water-sharing agreement process.

For more information, read *Towards Restoring Flows into the Earth's Arteries: A Primer on Environmental Flows* by Latha Anantha (River Research Center) and Parineeta Danekar (South Asia Network on Dams Rivers and People): www.internationalrivers.org/node/7508.

An example from Practical Action of an early flood risk warning system to reduce flood impacts includes:[29]

- A watch tower for villagers to scan waters rising to dangerous levels. They are able to sound a siren, which can be heard up to 3.2 km away.
- Rain/flood gauges to monitor potential risk.
- A bridge to create an escape route for the community at risk.
- Emergency shelters with toilets and clean water pumps are built on higher ground. Outside of monsoon season, the shelter can be used as a school, so the facilities can be made good use of all year round.

A depiction of an early warning system for disasters by Practical Action

An example of people-driven flood forecasting comes from River Basin Friends in India. River Basin Friends is a people's network of more than 300 organizations focused on the Ganga-Brahmaputra-Meghna basin. Official flood forecasting from the central government is often insufficient to predict impacts at the local level, and the information cannot usually reach people in vulnerable locations. So River Basin Friends began its own initiative to commence an early flood warning mechanism that reaches people all the way downstream in Bangladesh. It has more than 1,000 members of different disciplines, living in different parts of the basin, who help circulate flood forecasting messages from upstream locations to downstream locations, using phones and email. People in the central hub in Assam collect information from different sources, and the peoples' network in upstream locations process and analyze it. The final flood early-warning messages are then formulated for different vulnerable locations and disseminated.

Ensure Climate Risk Management Throughout the Entire Life Cycle

All phases of the project life cycle should have assessments of climate change risks and impacts, starting from water and energy plans and through to SEAs, SEIAs, and monitoring plans. However, these tools, along with dam-industry-developed tools like the Hydropower Sustainability Assessment Protocol (HSAP), are very stationary as currently formulated and do not give adequate consideration to climate risks. Assessments of climate risks and impacts should occur as early as possible, beginning with the selection of infrastructure alternatives, and such assessments should be done at a regional scale in order to identify trade-offs and plan for a wide range of impacts. See *Appendix 3: Table of Key Questions for Assessing Climate Risks of River Projects* for a list of questions you can ask about different categories and for all stages of the process.

Repaying a Climate Debt: Making Climate Finance Transformational

By Janet Redman, Co-Director of the Institute for Policy Studies, Washington, DC

"Climate finance" is a catch-all phrase for the money and financial services governments need to fund activities that lower their greenhouse gas emissions in order to keep the planet from reaching dangerous temperatures ("mitigation"), and the resources needed to cope with the warming that's already locked in ("adaptation"). In 2008, Nicholas Stern, author of the UK government's study of the economic costs and benefits of climate change, estimated that the cost of averting climate disaster will be 2% of global GDP per year by 2050. But Stern's calculations didn't get to the heart of one of the most contentious issues in the debate around a global climate agreement – who pays.

The UN climate convention, signed by 192 countries, gives clear directions on which countries are responsible for footing most of the bill. It states that developed countries must "provide new and additional financial resources" to developing countries to cover the cost of shifting from business-as-usual, fossil-fueled economic expansion to low-carbon development pathways. It also commits developed countries to help developing nations meet the costs of adapting to the adverse effects of climate change – a problem they did not create.

Developed countries' historical responsibility for the climate crisis is called "climate debt." Climate debt recognizes the fact that while they are home to only 20% of the world's people, wealthy industrialized countries are responsible for releasing more than three-quarters of all greenhouse gas emissions already in the atmosphere. This means that rich nations have used more than their fair share of the global carbon budget. It also means that if we are going to limit global warming, poorer countries cannot follow the same fossil-fuel-intensive development path that industrialized countries took to getting rich. There's just not enough space left in the atmosphere for all that CO_2.

So where does that leave developing countries? A growing number of developing governments and civil society groups are demanding that rich countries repay their climate debt in two ways. First, they must immediately and drastically lower their greenhouse gas emissions so that enough of the shrinking carbon pie remains for poorer nations to meet the basic needs of their people.

Second, developed nations must pay for damages already incurred from climate change, and compensate for the portion of the global carbon budget they consumed that rightfully belonged to the 80% of humanity living in the developing world. The price tag is still up for debate, but the World Bank's World Development Report 2010 pegs the cost of mitigation in developing countries at US$400 billion a year for at least the next 20 years, and adaptation at $100 billion annually in the next four decades. Environment and development NGOs have called for at least $150 billion of that to come from public finance from industrialized nations. The Group of 77 and China, a negotiating bloc currently representing 132 developing countries, is calling for the transfer of 1% of developed countries' GDP each year.

Quality, Not Just Quantity

Development experts, environmentalists and grassroots organizers from across the political spectrum are quick to point out that money alone isn't going to solve the climate crisis. The rules that govern how money flows, and what activities it supports, will in large part determine whether climate finance is truly transformational.

A climate debt approach is useful here, too, for thinking about *how* to provide climate finance. It acknowledges that the way industrialized countries grew wealthy – by exploiting and exporting natural resources out of poorer nations – actively impoverished people in the Global South. Therefore, repaying the climate debt should help undo historical harm by establishing financial rules and mechanisms that uphold developing country governments' sovereign right to determine their own low-carbon development pathways. But even beyond the national level, just and effective climate finance must support the local, democratic control of natural resources, as well as promote poverty eradication and climate-friendly development.

The good news is that lots of people from all over the planet have come up with some common principles to guide the development of fair and effective climate finance. First, any financing scheme must be democratic, transparent and accountable to all, with civil society formally represented in decision-making arrangements. Also, community-based groups (in addition to government agencies) should have direct access to funds. The Global Fund to Fight AIDS, TB and Malaria has successfully shown that when civil society cuts out the middle man (for example, the World Bank and other international financial institutions), they can better and more efficiently meet peoples' needs. In addition, a global climate finance regime must respect and protect the right of all people – particularly indigenous people and local communities – to determine their own development path, decision-making processes, and activities related to climate change.

For the full article, see:
www.internationalrivers.org/node/1731

This micro-hydro plant in Cameroon leaves the river intact and floods no land. It can also be built and operated by local people (unlike megadams). Photo: Terri Hathaway

Finding Solutions to Adapt to Climate Change

While human beings have been adapting to environmental change for millennia, climate change is bringing bigger and faster changes than most human societies have had to deal with. Key changes that pose the greatest challenges for adaptation include increases in temperature, more extreme storms and worse flooding, ongoing changes in intensity and duration of precipitation, new health and disease challenges, and major changes to key ecosystems.

National adaptation plans the world over are largely state-driven and purely top-down in terms of their decision-making approach, while climate change is experienced locally and can only be effectively addressed by engaging local groups and institutions.

Local agencies, especially civil society organizations, are often best suited to improving adaptive capacities within vulnerable communities because they are closest to the problem. At the same time, a local organization may not have the necessary resources and expertise to conduct detailed assessments of climate risks. Engagement with local or regional experts and government agencies that do have the resources and expertise is thus an important piece in developing adaptation options.

In any case, resilience strategies should be an integral part of research, development, planning, training, capacity building, and project implementation.[30] This chapter describes some of the key principles of climate resilience and offers suggestions on how you can work with your organization to develop adaptation activities and sustainable solutions. It also includes a series of case studies of successful adaptation solutions by sector.

PRINCIPLES OF CLIMATE RESILIENCE

Climate resilience can refer to actions that either reduce climate impacts or respond to climate impacts. More specifically, resilience deals with reducing the vulnerability of natural and human communities to climate change impacts by strengthening their ability to deal with both ongoing and one-off disturbances generated by climate change (for instance, through improving local food security or energy access).

When developing an adaptation project or a development project with adaptation components, it is important to keep the following principles of climate resilience in mind, in order for the project to be sustainable and for local communities to be resilient to major climate-related impacts (adapted from the Institute for Social and Environmental Transition).[31]

Access Rights and Stewardship

It is important for local community members to control local natural resources. For instance, securing the land rights of indigenous populations allows them to increase their ability to adapt to the pressures of climate change. Sometimes with the support of pro bono lawyers, your group can work with community members to clarify their rights and entitlements to use key resources and ensure that these do not exclude specific groups from access to critical resources or support systems. Successful stewardship of natural resources also involves community monitoring of infrastructure projects and citizen science. This helps in building resilience as communities are more aware of project functions and associated risks. Communities that play a central role in the operation and maintenance of irrigation systems can also help build resilience.

Adaptive Capacity: A core principle for strong adaptation and resilience is improving the adaptive capacity of the affected community and those involved. This concept can mean being resourceful, responsive and having capacity to learn from past experiences. It is essential that civil society groups and other institutions involved in climate adaptation activities have a strong and locally driven understanding of the vulnerability of the poorest and most at-risk communities. Poor governance and weak institutions are often cited as the main drivers of vulnerability, and lack of local participation and investment in community-based climate adaptation strategies are significant barriers to a community's adaptive capacity. Your group can help by bridging the gap between government and local communities at an early stage. For example, local and transboundary civil society groups established an Early Flood Forecasting system for rivers in the flood-prone Assam in North East India, which has helped to increase the climate resilience of vulnerable communities.[32]

Diversification and Decentralization: A resilient system is one where key assets (such as water and energy sources) and functions are physically distributed so that they are not all affected by a climate-related event or natural disaster at any one time (spatial diversity) and have multiple ways of meeting a given need (functional diversity). For instance, a diversified and decentralized energy portfolio allows a state, province or country to be more resilient to extreme climate events that might shut down a source of energy in one region but would have a limited impact on other areas. In the water sector, diversified cropping patterns and ecological farming practices can help farmers weather droughts, floods or mismanagement of systems. Riverine fisheries supported by free-flowing rivers aid in nutritional security in times of stress.

Villagers along the Teesta River in Bangladesh at a community-building workshop in Sikkim, India. Photo: Samir Mehta

Flexibility: Because climate change implies a future of uncertainty, flexibility is a core underlying principle that applies to essentially all areas of adaptation: infrastructure, projects, institutions and governance. Faced with such an uncertain future, your group can promote "no-regrets" strategies that address key development priorities and are justified even if climate change was not an issue. For instance, if water resources seem to be declining, reducing demand through increased efficiency may be a more flexible (and precautionary) solution than building a dam, at least until there is more certainty about how much water will be available.[33]

Good Governance: Decision-making processes should follow widely accepted principles of good governance, chiefly: transparency, accountability and responsiveness. Your group can urge your government to recognize that the community groups that are most affected have a legitimate claim for being involved in decision-making processes. Decision-making processes should also be transparent, representative, timely and accountable; include avenues for affected parties and different interest groups to provide input including complaints; and ensure that dispute resolution processes are accessible and fair.

Information Flows: Your group can assist in collecting and disseminating accurate and meaningful information to households, businesses and the public so that they can make judgments about risk, vulnerability and adaptation options.

Redundancy: In order to prepare for emergency situations, governments and institutions should be equipped to provide various service delivery options. Your group can assist in this by channeling aid and funding to disaster-stricken communities. This concept of redundancy also includes the presence of buffer stocks (for example, local water or food supplies) that can compensate for the loss of critical resources and support systems if resources or service flows are disrupted.

KEY RECOMMENDATIONS FOR CIVIL SOCIETY GROUPS

Selecting/Designing Sustainable Solutions

If you are in charge of developing a project or program, ensure that it follows the *Principles of Climate Resilience* (see above) and also meets the following specific criteria:

- Helps vulnerable groups: The most vulnerable groups or sub-groups within a community have the greatest need to increase their adaptive capacity; therefore, activities that meet the needs of these groups should be emphasized.
- Number of beneficiaries: Balance the first criterion with a goal to benefit as many people as possible.
- Sustainable "no-regrets" solution to climate change: The proposed activities should take into account the impacts of climate change in the long-term and bring benefits even in the absence of climate change impacts.
- Grounded in sound science and local context: As much as possible, ensure that the project marries both bottom-up (vulnerability analysis) and top-down approaches (climate science projections).
- Political feasibility: While you want a project that ideally receives political and financial support, encountering political opposition should not be seen as an insurmountable barrier or a limitation on innovative thinking.

Lake Chad, once the fourth largest lake in Africa, has lost 80% of its surface area in the past 30 years due to dams, diversions, and shifting climate patterns. It can now be crossed on foot. Photo: Cédric Faimali

- Cultural appropriateness: Adaptation projects and activities also need to respect the local culture to be feasible. Otherwise, you may find that changes are not widely adopted. Similar to the previous criterion, this should not rule out change, as deeply rooted behaviors may be part of the problem.

- Long-term cost effectiveness: Less costly solutions should be preferred for obvious reasons; however, cost effectiveness should be considered over the long term, as adaptation solutions will by their nature often only pay off in the long run. Cost assessments therefore need to take into account not only the immediate implementation costs of the project, but also the avoided future costs of climate impacts.

- Greenhouse gas emissions: While reducing the carbon footprint may not be a priority for local development of poor and vulnerable populations, low-carbon development should be pursued whenever possible.

When you have come up with an appropriate project, make sure that it has community support and ownership, and determine that you share a common, clear definition of the impact that you are hoping to achieve. Make sure that your solutions will not create secondary challenges or future problems. Make a plan and timeline for designing, funding, launching, managing, and handing over the project to the community. There are number of resources for this in *Appendix 1: Key Resources.*

Ensure Solutions Address the Needs of the Most Vulnerable:

Projects that tamper with or destroy natural resources – such as major river engineering projects – should be evaluated for how they will affect the adaptation capacity of the most vulnerable. Further, because poor communities often do not perceive adaptation as something new or separate from how they have always been living with their environments, the following practitioner's perspective in working with the most vulnerable populations on climate adaptation can be useful:

- Learn from what exists: A sensitivity to natural adaptation patterns is required to learn how a specific community experiences climate change and what natural adaptation methods could be built upon for climate adaptation.

- Customize solutions: Adaptation processes differ across geographic, physical, and cultural contexts. Synergy among practitioners from similar contexts can lead to new solutions for specific communities.

- Link to livelihoods: For communities living in poverty, meeting basic needs is a priority. Adaptation processes that directly enhance local livelihoods more easily become community-driven, and hence sustained.

- Create local knowledge paths: Challenges of convincing a community to adopt an unfamiliar adaptation solution can be overcome by developing village-to-village mentorships. A community that has proved the efficacy a new adaptation process would be the best knowledge agent for others facing similar climate risks.

You can find a wealth of resources around solutions that have worked on Practical Action's website: www.practicalaction.org/climate-change.

TYPES OF SOLUTIONS BY SECTOR

The following sections present specific adaptation solutions in the water, energy, food and conservation sectors, and case studies where they have been successfully implemented. They include examples from both "supply-side" management, which includes increasing capacity (such as building new structures) and changing operating rules for existing structures, and "demand-side" management, which includes managing demand and changing institutional practices.

WATER SECTOR

Climate change will bring huge and complex challenges to the water sector, and a great variety of adaptation strategies will be needed to tackle them. Climate change will impact the amount and quality of water that is available. Water supplies will become less predictable. Water-related extreme events will become more frequent. Reduced water availability will pose an ongoing threat to ecosystems.

The area of hyper-arid land increased by 100% between the 1970s and 2000s.

Over the past several years, there has been an increase in interest in demand-side techniques, as certain supply-side strategies such as building more storage reservoirs or large water diversions have proven to increase some problems of adapting to a changing climate – for instance, they can evaporate great amounts of water due to higher temperatures, and pose a greater risk of damage or failure from more extreme floods. Decentralized local storage options generally provide greater accessibility and flexibility for local water users. While many regions will need greater water supply, many bodies such as the World Bank continue to promote hard-path, large-scale infrastructure as an adaptation response rather than more resilient strategies, such as some of the examples presented in this chapter (see "World Bank's IDA and Climate Resilience" on next page). Climate adaptation strategies and alternatives to large water storage from dams vary greatly and encompass a variety of approaches including better water management strategies, small-scale water storage, and alternative agricultural practices. Some of these examples are described below.

Rainwater Harvesting and Groundwater Recharge

Around the world, community groups have developed locally practical rainwater harvesting systems. These systems will be of increasing importance in a changing climate because they can be more accessible and dependable than a centralized large water storage facility, especially for the rural poor who are located in remote regions. Unlike large infrastructure projects that often bypass the rural poor, small-scale rainwater harvesting projects are managed locally, and are simple and cheap to build and operate. Local people can be easily trained in such technologies, and construction materials are usually locally available. Rainwater harvesting is convenient, because it provides water at the point of use and farmers have full control of their own systems. It can also help to increase soil moisture levels and groundwater through artificial recharge. Its main limitation is the availability and amount of rainfall.[34]

Man stands next to a johad, or small dam, built to impound rainwater in India. Photo: Patrick McCully

For example, in Thailand many rural people collect rainwater for drinking and cooking in large jars near their houses. More than 10 million rainwater jars have been built in Thailand. The jars come in various capacities, from 100 to 3,000 liters, and are equipped with lids, faucets, and drains. The most popular 2,000-liter jar holds enough rainwater for a six-person household during the dry season, lasting up to six months.

India has a long history of community water systems, and in recent decades a rainwater harvesting movement has been underway, especially in the driest parts of the country. Villagers in Rajasthan, for example, have built or restored thousands of water-harvesting structures, with the help of NGO Tarun Bharat Sangh. Known locally as *johads*, these small rock or earthen dams are built across seasonal water courses to capture monsoon rains, restrain soil erosion, provide irrigation water, and restore the groundwater. Along with other water-conservation structures and strategies, they have brought water back to more than 1,000 villages and revived five rivers in Rajasthan. *The Hindu* newspaper summed up this remarkable water harvesting work in Rajasthan: "The poor should not always have to pay a price for the government's constant search for ineffective mega-solutions and critical neglect of micro-problems. The people only need to be given a sense of hope to achieve the impossible."

Several examples of community-centered small-scale water systems exist throughout India, especially in the biodiversity hotspot of the Western Ghats. These are not just one-off success stories, but a mainstay of many drinking water and irrigation systems. For

CATEGORIES OF ADAPTION MEASURES IN THE WATER SECTOR[1]

Adaptation Measures	Examples
Planning and implementing new investments	Reservoirs, irrigation systems, rainwater harvesting, groundwater recharge facilities, levees, water supply, wastewater treatment, desalination plants,
Adjusting operation, monitoring, and regulation practices of existing systems to accommodate new uses or conditions	Pollution control, environmental flows in dam operation, ecosystem restoration
Working on maintenance, major rehabilitation and re-engineering of existing systems	Dams, barrages, irrigation systems, canals, pumps, rivers, wetlands
Making modifications to processes and demands for existing systems and water users	Water conservation, pricing, regulation and legislation, basin planning, funding for ecosystem services, consumer education and awareness
Introducing new water-conserving technologies	Biotechnology, drip irrigation, wastewater reuse

World Bank's IDA and Climate Resilience

By Peter Bosshard, Policy Director for International Rivers

The World Bank's International Development Association (IDA) is the most important source of development finance for the world's poorest countries. Donor governments are currently negotiating their contributions to the IDA. A new round of finance is supposed to support goals such as inclusive growth, gender equity and climate resilience.

Despite a commitment to climate resilience, the World Bank has accelerated its push for large dams, which could increase climate vulnerabilities in many regions. In March 2013, World Bank management proposed to make large regional infrastructure projects an additional focus of future IDA projects, including the Inga 3 hydropower dam on the Congo River (cost: US$10 billion) and the Mphanda Nkuwa and Batoka Gorge hydropower schemes on the Zambezi (expected total price tag: $8-9 billion). The Bank argues that such projects could "catalyze very large-scale benefits to improve access to infrastructure services," while ignoring the fact that these projects could also undermine IDA's commitment to climate resilience.

In a letter to donor governments, International Rivers and several partner groups argued that reducing climate vulnerability requires flexible, decentralized and diversified energy and water infrastructure. As climate change makes rainfall less predictable, putting all our eggs into the basket of large, centralized reservoirs increases vulnerability to climate shocks. Already, Sub-Saharan Africa is the world's most hydro-dependent region. World Bank and IMF experts have recommended that this dependence be reduced in the interest of climate resilience.

According to research by the Intergovernmental Panel on Climate Change, the Zambezi exhibits the "worst" potential effects of climate change among major African river basins. In spite of this, the Mphanda Nkuwa and Batoka Gorge dams, which the World Bank proposes to fund, have not been evaluated for the risks of reduced annual streamflows, more extreme floods and extended droughts that are associated with a changing climate.

Representatives of the community that would be affected by Inga 3 on the Congo River (with International Rivers' Rudo Sanyanga, lower left). Photo: International Rivers

In March 2013, governments rejected the World Bank's proposal to add regional infrastructure initiatives to the focus topics of future IDA projects. The World Bank could take this decision as an opportunity to change direction and prioritize decentralized, renewable technologies with a better potential to reduce poverty in Africa. The Bank's new leadership has, in theory, the best intentions around clean energy and say they are accelerating large dam development because they want to reduce GHG emissions. However, they are doing so without considering climate adaptation. International Rivers and partner organizations will continue to monitor the IDA and other World Bank financing mechanisms.

instance, the Chauka system of water harvesting increases fodder and protects biodiversity. Integral to these is community ownership of grazing lands and a central role in decision-making and management.[35]

These and other initiatives that harvest rainwater also help recharge groundwater. In the dry state of Maharashtra, India, for instance, the NGO Watershed Organization Trust, aided by the German government, worked directly with villagers to form village watershed committees to restore their watershed, improve crop yields, and increase water availability. Through building check dams and hillside contour trenches, banning grazing on hillsides, and planting trees and grasses, groundwater aquifer levels rose by three meters, in spite of several drought years. Irrigated acreage doubled, and water trucks delivering water during the dry months were no longer needed.[36]

In Kenya, more than 500 sand dams have been built in the Kituï District to store rainwater and restore groundwater, similar to the check dams in India. Sand dams are a simple, low cost technology that can be built by local people using easily available materials. A sand dam is a low wall (2-4 meters high), typically built across a seasonal sand river to store water when

A community builds a sand dam in Kenya. Photo: Excellent Development

it rains. The RAIN Foundation reports that some Kituï sand dams have been in operation for 25 years. This strategy has also been successfully implemented in the Borana zone of southern Ethiopia by Action for Development, and several Ethiopian NGOs have been trained to construct similar sand dams in other regions.

Sand dams to restore groundwater have been constructed in Kenya, Ethiopia, Angola, Zimbabwe, Japan, India, Thailand, the US, and Brazil, providing water to thousands of people.

Africa has great potential for developing more rainwater harvesting. About a third of Africa is considered suitable for rainwater harvesting, according to a study by the United Nations Environment Programme (UNEP) and the World Agroforestry Center, which states that: "As we look into what Africa can do to adapt to climate change ... rainwater harvesting is one of those steps that does not require billions of dollars, that does not require international conventions first – it is a technology, a management approach, to provide water resources at the community level."

Artificial Glaciers

A retired engineer in India's Ladakh region has found a way to make artificial glaciers. In this cold desert region, the only source of water is glaciers, whose waters flow into Ladakh too late in the summer for farmers to use. Chewang Norphel has developed a way to create artificial glaciers that bring water to the fields in spring.

Norphel's glaciers are easy to build. First, the workers channelize glacier water into a shallow pool in the shadow area of a mountain, hidden from sunlight. Half-inch-wide iron pipes are placed at its edge. As the water keeps collecting in the pipes, it freezes. As more water seeps in, it pushes out the frozen blocks, and is frozen in turn. These frozen blocks create a clean, artificial glacier. The shallow pools melt faster than natural glaciers, and the water can be used for spring planting. By 2012, Chewang Norphel had built 12 artificial glaciers; the largest is 1,000 feet long, 150 feet wide and 4 feet deep, and can supply water for a village of 700 people.

Norphel says his artificial glaciers are a better solution than large dams, which bring enormous financial burdens and environmental and social hazards. Big reservoirs also evaporate water more quickly in the bright mountain sunshine. As the Himalayan glaciers melt, the artificial glaciers will stop being an effective solution – but for now, it's an ingenious local solution for water harvesting.

Flood Management

Flood management in a time of climate change must focus on improving flood-coping mechanisms and flood-preparedness. Some key areas that must be addressed include sustaining and improving natural systems' ability to absorb floodwaters; improving dam management and instituting clearly defined and transparent dam operating rules that are stringently enforced; improving the maintenance of existing flood infrastructure rather than spending money on new dams and embankments; and producing transparent disaster management plans intended to be implemented in a participatory way. Community networks like River Basin Friends in India's Brahmaputra Basin provides an excellent example of people-powered early flood-warning systems (described on page 35).

In Europe, a number of rivers are being "de-engineered" to restore their floodplains. The six countries through which the Rhine flows have been taking steps to restore its floodplain ecosystems. In 1998, the International Commission for the Protection of the Rhine adopted a 20-year Action Plan on Flood Defense. Key components of the plan include the removal of embankments and restoration of river and floodplain ecosystems, and improved flood mapping, education, warning and evac-

Chewang Norphel watches over construction of a shallow pool, which will hold an artificial glacier in the Ladakh region of north India. Photo: Ecofriend.com

Finding Water Through Demand Management in Southern Africa

Southern Africa water experts agree: water demand management can reduce water consumption by at least 30% in most cities. Moreover, these savings can be achieved with no noticeable reduction in quality of service, nor at any long-term cost to consumers. In fact, some cities in the region have already achieved significant reductions through demand management. Windhoek, Namibia achieved 33% reductions through pricing strategies, appliance upgrades, water re-use and other measures. The cost of these savings was less than one-tenth the cost of developing new sources being considered at the time, such as piping water from the Okavango River 700 kilometers away.

A 12-point water conservation program in the city of Hermanus, South Africa reduced water demand by 32%. The program included measures such as promoting water-wise gardening, improving the metering system, removing thirsty alien vegetation from water catchment areas and conducting water audits in schools and homes. Revenue from water sales increased by 20% despite the decreased demand. Because water "produced" through conservation and managing demand can be 65-80% less expensive than water developed through new infrastructure, water is now more affordable to the poor.

Farming in southern Africa consumes more water than any other sector by a wide margin: 80% in Mozambique and Zimbabwe, 66% in Namibia and 60% in South Africa.[37] By contrast, the domestic and industrial sectors typically account for less than 15% each. If South African irrigators – and especially large-scale agribusinesses that use the most water – could improve efficiency by only 20%, water available for urban or industrial use would be doubled.

Another area of water use that needs further examination in southern Africa is the coal industry. A Greenpeace report, "The True Cost of Coal in South Africa," notes that for every unit of electricity produced, the new Kusile coal plant will use 173 times more water than wind power. Coal requires a huge amount of water to mine as well as burn in power plants, and has the added problem of polluting groundwater sources. As water grows increasingly scarce in South Africa, farmers fear they will begin to lose water rights to the national utility, which has precedence over other users for water.

uation systems. More natural floodplains are also being restored for Austria's Drau River, France's Loire River, and Germany's Elbe River, which experienced major floods in 2002 and 2013.

Green Infrastructure

Because the approaches we have used for centuries will not solve the new water challenges we face with climate change, experts around the world are promoting "green infrastructure" for addressing floods and water management. This approach, which relies on natural greenways and wetlands to absorb floodwaters, is a cost-effective and flexible way for local governments to deal with the impacts of climate change. It has three critical components:

- Protect landscapes like forests and small streams that naturally sustain clean water supplies.
- Restore degraded floodplains and wetlands so they can better store flood water and recharge streams and aquifers.
- Replicate natural water storage systems in urban settings, to capture rainwater and prevent stormwater and sewage pollution.

In Peru, the environment ministry and local organizations have developed several adaptation measures, including the storage of water in highland wetlands (*bofedales*), storing water in small-scale reservoirs, improving irrigation practices (including expanding drip irrigation), the introduction of drought-resistant crops, and studying the potential effect of preserving native forests on groundwater storage.

In China, local governments and NGO partners are restoring wetlands and lakes for natural flood control, as well as wildlife habitat restoration. In 1998, a flood in the Yangtze Basin breached 2,000 embankments, inundated 28,500 square kilometers of agricultural land, and left 2.5 million people homeless. The disaster prompted Beijing to pass a Flood Control Act that signaled a shift from a dependence on structural flood control to greater use of non-structural measures. One such project, managed by WWF-Beijing and local governments, is a restoration initiative that will restore 20,000 square kilometers of wetlands in central China. In addition to flood protection, the project will also improve fisheries and give a boost to migratory birds. Wildlife species have begun to return to restored areas.

From 1999-2008, floods affected almost one billion people in Asia, 28 million in the Americas, 22 million in Africa and four million in Europe.

Highland wetlands in Chile. Photo: Javier Ignacio Acuña Ditzel

ENERGY SECTOR

Many forms of electric power production are extremely vulnerable to climate change. Extreme weather events threaten infrastructure, and drought threatens hydropower production. Changing wind patterns could reduce wind-power potential, while increasing clouds could interfere with solar power. More robust design specifications for energy infrastructure projects that allow structures to withstand more extreme conditions and accommodate incremental changes over time can be more climate-resilient. Local, diversified energy systems like micro-hydro plants and wind and solar systems, while vulnerable to climate change individually, can form a resilient energy network if developed together and with back ups.

In a report on energy sector vulnerability and adaptation to climate change, the Asian Development Bank (ADB) makes the following recommendations for energy sector planning for adapting to climate change[38]:

- Introduce climate change vulnerability and adaptation considerations to criteria used for selecting and prioritizing projects.
- Develop sector-specific and country-specific screening tools to identify proposed projects at risk.
- Incorporate budgets for specific adaptation interventions, including estimates of the likely costs, risks, and benefits of adaptation action and inaction.
- Adjust zoning regulations for energy infrastructure (for example, to avoid flood or permafrost zones).
- Design flexible energy infrastructure (for example, use more robust design specifications that could allow structures to withstand more extreme conditions).
- Incorporate climate change indicators into energy planning and budgeting.

ENERGY NEEDS AND DECENTRALIZED RENEWABLE OFF-GRID SOLUTIONS[2]	
Cooking	Biogas from small scale digesters; solar cookers; clean stoves and clean fuels
Lighting and other small electric needs	Small hydropower; biogas from small digesters; small biomass gasifiers and gas engines; wind turbines; solar home systems; solar LED lanterns
Power generation for productive uses	Small, micro and in-stream hydro and electric motors; biomass power generation; biomass gasification
Water pumping for home use and irrigation	Mechanical wind pumps; electricity from micro to small hydropower; solar PV pumps; treadle pumps
Heating, cooling and refrigeration	Biogas combustion; solar crop dryers; solar water heaters; cooling through small electricity systems

Climate Change Adaptation in Uganda

By Geoffrey N. Kamese, Senior Programme Officer, the National Association of Professional Environmentalists (NAPE), Kampala, Uganda

A Solar Sister training in Uganda. Photo: Solar Sister

Uganda is one of the world's least developed countries and highly vulnerable to the impacts of climate change. According to Uganda's National Adaptation Programme of Action (NAPA), the country has been experiencing an average temperature increase of 0.28°C per decade between 1960 and 2010, with the months of January and February being the most affected, averaging an increase of 0.37°C per decade. The frequency of hot days in the country has significantly increased, resulting in severe drought and water scarcity among many communities who are increasingly becoming water stressed. This has in turn resulted in communities generating and regenerating knowledge, practices and innovations to enable them to adapt to the changing climatic conditions in the country.

The Ankole region in Uganda is one of the most seriously affected by climate change and is among the most water stressed in the country. The water stress in the region has mainly been due to prolonged dry seasons and unpredictable rainfall. As an adaptation strategy, many rural communities have constructed both surface and underground rainwater harvesting tanks; this is in addition to the numerous small dams that are located in different parts of the region mainly to provide water for livestock. The communities contribute finances, materials and labor for construction. Some support also comes from NGOs and the local government. For some very poor communities, water tanks have been constructed using mud and wattle and other low-cost materials. These rainwater tanks provide safe water for drinking and for other uses at the household level, as well as water for small-scale irrigation.

While there has been effort and some success towards the implementation of community adaptation projects, a lot is still required. The impacts of climate change in Uganda have been devastating and become increasingly complex and difficult to address with indigenous knowledge. Many adaptation strategies today require large amounts of money, yet such funds have not been appropriately disbursed. Adaptation funds are essential to, among other things, support sizeable water storage tanks, facilitate the provision of drought-resistant crops in some places and flood tolerant crops in others, provide appropriate energy technologies, and raise awareness among communities on the impacts of climate change and key adaptation strategies. Unfortunately, while the government of Uganda has put in place a climate change policy, there is no specific budget in place to address climate change impacts. Climate change is considered to be a cross-cutting issue, and it often does not receive the attention it requires. There has also not been sufficient support from the international community to support adaptation activities in poor countries. All these present a major challenge toward the implementation of community adaptation projects.

Adaptation to climate change impacts in least-developed countries is critical and must be addressed by development planners. First and foremost, we need greater recognition of the importance of community participation in the planning and implementation process of large development initiatives. The guiding principle in any development process should be to improve the livelihoods of the people, to sustain development in the community, and above all to respond to community energy and water needs.
In the case of large dams, planners must recognize that access to water is a fundamental human right that must be respected at all times. It is also imperative that governments, dam planners and financiers respect and address the energy and water needs of the communities as key strategies to adaptation. Governments and financiers must identify and support energy options that can be easily owned by the people not only to ensure energy security but also to ensure community energy sovereignty.

For more information on NAPE, see: www.nape.or.ug

In practice, however, according to the South Asia Network on Dams, Rivers and People, the ADB is funding and supporting large hydropower projects in the Indian Himalayas, one of the most vulnerable regions with respect to climate change, without using any of these criteria.

Hydroelectric power is often touted by industry groups as a reliable source of base-load energy, as well as an effective source of peaking power, since it can be turned on and off quickly. However, as we saw in Chapter 2, it can also be very vulnerable to climate change, as its performance is dependent on water inflows to reservoirs and a predictable hydrological cycle. While both large-scale hydropower and small-scale decentralized renewable energy projects (such as wind, solar, micro-hydro, and biomass) can provide adaptation, mitigation, and poverty-alleviation benefits, decentralized and distributed renewable energy sources are more likely to support livelihoods, and increase local autonomy over energy sources.[39]

DECENTRALIZED OPTIONS	BENEFITS OVER LARGE HYDROELECTRIC DAMS
Solar (community lighting systems, portable solar PV, lights, village solar pumping systems, and solar water heaters)	Direct access, no grid connection needed, is locally managed and/or owned.
Wind pumps (home use and irrigation)	Provides relief from water stress and energy for water pumping in otherwise energy-deprived areas, energy source diversification.
Micro-hydro	Local watershed conservation, local management, overcoming energy equity issues of large hydropower, and empowerment of local livelihoods.
Biomass (straight vegetable oil systems and biogas from small-scale digesters)	Direct access, no grid connection needed, locally managed, and diversification of a range of local energy sources.

Building Local Economies with Solar

Solar power is becoming more and more widely available for purchase, and is relatively easy to install and maintain, making it an ideal candidate for a community-owned energy system. Many of the millions of people who lack access to electricity live in places where the sun shines steadily and connection to the national grid is a distant prospect. The price of solar panels has dropped dramatically in recent years, and while affordability remains an issue for the poorest, solar is the most cost-effective way to electrify huge swaths of the world's off-grid regions.

New models of distributing systems are helping get systems in place. For example, the Solar Energy Foundation has distributed over 19,000 solar home systems to rural areas throughout Ethiopia, established regional "solar centers," across the country, and is training technicians and installers.

In Rwanda, Uganda and South Sudan, Solar Sister (a social enterprise comprised of over 170 female entrepreneurs) uses a direct-sales network that allows women to build their own businesses in remote areas. By selling a variety of high-quality solar products through their networks, Solar Sisters are not only spreading solar light throughout the region, they are creating economic opportunities for themselves as entrepreneurs.

The limitations to solar include a number of bottlenecks such as training for the installation, operation and maintenance of new and existing systems, and accessing credit to pay for and install them. Scaling up distribution with national and international financial support, as well as shifting the balance of support for renewable decentralized energy sources over conventional large-scale projects, should become a much higher priority for governments and major financial institutions.

Energy Efficiency

Improving energy efficiency should be made a top priority for all nations, because efficiency measures are cheaper, cleaner and faster to install than any other energy option. For instance, in India, up to half of hydropower projects are generating at less than 50% of their installed capacity while 89% have never generated at their installed capacity. In such a situation, even without considering transmission losses, end-use efficiency and demand-side management, there is huge scope for making the existing infrastructure more efficient.[40]

Women trained by Barefoot Solar Engineers in India electrified this village in Rahasthan. Photo: Knut-Erik Helle, justworldphoto.org

Tajikistan has been in an energy crisis since 1997. Its cold climate and poor infrastructure meant that much of the population relied on local firewood and dung for household energy. Huge amounts of wood were being burned to heat houses during the five-to-seven month long winters. With help from the German government, energy efficient products were introduced into local markets, and local craftsmen trained to produce and install efficient windows, house insulation, solar water heaters and fuel-efficient stoves. Local micro-finance programs were expanded to cover the efficient products. Household fuel consumption for cooking and heating has since been reduced by 30-50%.

Developing countries, which will account for 80% of global energy demand growth to 2020, could cut their demand by more than half using existing technologies to improve energy efficiency, according to McKinsey Global Institute.[41] Energy savings can be found even in countries where energy use is just beginning to take off. In fact, putting efficiency measures in place now for growing economies can save money to invest in other pressing needs.

Below are a number of steps that civil society groups can recommend to governments and utilities:

- Develop strong building and appliance standards and promote the aggressive deployment of energy-efficient technologies and strategies. To be effective, these standards should be mandatory and tightened regularly.
- Break the link between utility sales and revenue. Known as "utility decoupling," disassociating a utility's profits from its energy sales is a necessary step to encourage utilities to pursue a path of energy efficiency over expanding supply. Without decoupling, a utility will be more focused on energy sales rather than meeting its customer's energy needs.
- Establish standards for utilities. While decoupling in and of itself will not cut electricity demand, it does mean that utilities can provide incentives for conservation programs without losing revenue. Enforceable targets for energy efficiency for utilities (also known as a "portfolio standard") will ensure steady progress. Other strategies to help utilities limit the need for new power plants include energy conservation, distributed renewables, and tactics to manage peak demand for electricity.
- Adjust energy prices to encourage ongoing efficiency. While this can be politically difficult in poor countries, blanket subsidies discourage efficiency and may benefit mainly those who are better off. Low-income communities can be protected from higher energy prices by subsidizing basic consumption and increasing unit costs for the heaviest users.
- Focus on the energy-intensive industries such as pulp and paper, mining, steel, cement, aluminum, petroleum refining and chemicals. Adopting the most-efficient blast furnaces and boosting recycling can cut energy use in the steel industry by close to 40%.[42] Converting China's cement industry to the most efficient dry kiln technologies, as used in Japan, could cut global energy use in the cement sector by 40%.[43]
- Increase awareness among consumers, businesses, building inspectors and contractors through education campaigns, labeling of appliances, and trainings. Giving energy users feedback on how much they use and where savings can be found can lead to significant savings.
- Transmission systems can be hugely wasteful. Africa's power grids, for example, lose twice as much electricity during transmission as do more modern systems.[44] "Smart grid" technologies, which use microprocessors and software to allow information to flow back and forth to all users in the system, would reduce electrical losses through the wires and enable a larger expansion of renewables within the grid.
- Create a carbon economy. Taxing high-carbon energy sources would help encourage companies to use energy more wisely and switch to clean renewables.

A solar water heater and shower designed by the local NGO Tajik Seeds. Photo: © Robert Middleton

- Address the water-energy nexus. Coal-based thermal power plants use huge quantities of water for cooling purposes. For instance, if India continues to build all its proposed thermal power plants, the country will need 18 billion cubic meters of water, enough to grow rice for 70 million people or provide 360 million urban dwellers with an adequate water supply.[45]

AGRICULTURAL SECTOR

Agriculture is a not only a large contributor to greenhouse gas emissions, it is also by far the largest consumer of fresh water. Some 40% of the world's food is grown in irrigated soils. Water waste on irrigated farms is a major problem globally, as is the pollution of freshwater sources by toxic farm chemicals. Experts say around half of water used in irrigation is wasted through unsustainable practices such as field flooding.[46] Activists can get involved in pressing for more efficient and equitable water use for agriculture in their regions, and a reduction in water pollution from farm chemicals and runoff. Both are critical for ensuring more sustainable water supplies for all.

Activists and civil society groups can also help small-scale and rainfed farmers practice sustainable farming, which will not only help them conserve water but also allows them to adapt to climate change. The practice of agroecology – the science of sustainable agriculture – can be used to help farmers of all scales improve their water management. Agroecology supports the development of drought resistant agricultural systems (including soils, plants, agrobiodiversity, etc.). Some ways it does this is by promoting the use of green manures and compost, which can increase the soil's water retention capacity from its current average of 1% to about 5% by increasing its organic matter content.[47]

In addition to encouraging farming systems that mimic how natural systems work, many farmers in dry areas could benefit from improved small-scale water storage systems. Farm-sized rainwater harvesting and groundwater recharge techniques can help the many millions of farmers whose farms are rain-fed. Contour plowing – in which soil is plowed in curved bands that follow the shape of the land – prevents soil erosion, and allows the water to settle into the soil. Other emerging practices, such as growing food in "micro gardens" in the world's developing cities, may not be a direct adaptation response, but because it can increase food security for the poor, it is a good "no-regrets" strategy.

Promoting wild vegetables and diverse seed banks can also improve community resilience. In tropical countries, rural food security depends in part on harvesting wild vegetable and fruits. Many NGOs in India, for instance, are working towards protecting seed diversity and the wild relatives of food plants. Subsistence farming in general, where home gardens provide the majority of nutritional requirements in a decentralized manner, should be strengthened and protected in order to promote climate resilience.

In the Mekong Delta, soil and water salinization has been a problem for decades. Damage from salinity is most severe during droughts or in early/late periods of the rainy season, and with an increasingly variable climate, salinity problems will only become greater.[48] The presence of dams leads to greater coastal salinity intrusion, since dams hold back sediments that help build the delta and also alter the natural hydrological cycle.

These climate change impacts call for robust adaptation measures to promote food security in the Mekong region. Many projects in the agricultural sector, for instance, focus on increasing resilience through adaptive crops and farm management strategies. A study by the Mekong Program on Water, Environment and Resilience that examined food production strategies for adapting to coastal salinity intrusion in Mekong delta areas listed these recommendations: salinity-tolerant rice varieties, adaptive shrimp farming, adjustment of cropping seasons, soil desalinization, and improved forecasting. The study also concludes that strategies such as increasing rice production in upper and mid-delta areas could make the investment in large-scale structural measures for dealing with food insecurity obsolete.[49]

Sri Lanka has experienced drops in groundwater levels and increased sea level in recent years. Farmers there have begun testing traditional and modern rice varieties for salt-tolerance, and greater resistance to pests and higher temperatures. Forgotten types of indigenous rice offer a local solution to this increasing soil salinity. There are around 2,000 traditional rice varieties in Sri Lanka. Many are very high in nutritional value and have medicinal properties, and most are resistant to extreme drought conditions, diseases and pests. Local farmers are testing different varieties of traditional rice with help from the National Federation of Traditional Seeds and Agri Resources and Practical Action. A few varieties have proved to be hardy, salt-tolerant and high quality rice well-suited for coastal rice paddies. These are now being promoted through local farmer organizations.

Dam Re-operation for Adaptation

Existing dams were not designed with a changing climate in mind. Some existing dam and reservoir systems can be managed better to restore ecosystem services and increase adaptation benefits and restore ecosystem services. Some of these strategies are described below.

For flood management dams:

- Use of floodplains to store and convey increased flood volumes (both through natural floodplain features and man-made basins/bypasses).
- Move levees and establish new floodplains to move floodwaters around populated areas.
- Reconnect floodplains to reduce flood risks and improve environmental management (for example, the Yolo Bypass floodplain reconnection in California, US).
- Remove silt from existing dams and catchment areas for optimal storage and flood control benefits.

For hydropower dams:

- Incorporate environmental flows into water release patterns. Flows that mimic natural river conditions can restore some of the natural seasonal hydrological patterns. (for example, the Murray Darling Rivers in Australia).
- To address daily fluctuations in flows: reregulating reservoirs, using off-channel pumped storage, and coordinating operations within a cascade of dams.
- Decommission dams that have outlived their usefulness or have a proven track record of causing and incurring losses.
- Improve power capacity generation.

For water-supply dams:

- Improve the performance and efficiency of existing dam and canal-based irrigation infrastructure.
- Improve integration of groundwater and surface storage by enhancing groundwater recharge using surface water from a water supply dam reservoir.
- Link the operation of multiple dams in a cascade/
- Change water delivery arrangements
- Combine environmental with consumptive water releases to meet flow targets more efficiently and with less water. (for example, the Murray River, Australia)

For case studies, see:
www.ecologyandsociety.org/vol12/iss1/art12

Reducing Water Waste in Farming

In traditional flood or center-pivot irrigation systems, 30-50% of the water is lost to evaporation or runoff. There are many ways to reduce this loss in farming. To give a few examples: irrigation can be scheduled to better match crop water needs; less-thirsty crops can be grown; and drip irrigation can be used to curb evaporation losses. Studies have shown that drip irrigation can reduce water use 30-70%, while actually increasing crop yields, compared with traditional flooding methods.[50] In addition, conserving "green water" – the water that is stored in soils and plants – through agroecology practices (which emphasize preserving the quality and water-retention ability of soils) can help reduce water waste, as well as having other benefits for farmers and the planet.

Another low-cost irrigation option being practiced in many developing countries is the treadle pump. In Bangladesh, treadle pumps have enabled farmers to irrigate their rice paddies and vegetables at a cost of less than US$35 per system. More than 1.4 million have already been sold in Bangladesh.[51] The pump can be locally manufactured and has been adopted by millions in India, Nepal, Burma, Cambodia, Zambia, Kenya and South Africa.

One unique effort to grow a staple crop with less water has been developed for rice. Rice is one of the world's most important staple crops, but uses large amounts of water. The International Rice Research Institute estimates that if conventionally grown, it takes 5,000 liters of water to produce one kilogram of rice. Agricultural scientists have made huge breakthroughs in reducing the amount of water needed to grow rice, while improving yields. Researchers at Cornell University and the Association Tefy Saina have developed a "System of Rice Intensification" that reduces water use by 50%, increases yields by 50-100%, and does not require expensive chemical inputs or hybrid seeds. (Similar systems of wheat intensification, crop intensification, and sustainable sugarcane initiatives have been developed that can contribute to efficient water use and conservation). An estimated 90% of agricultural water used in Asia is for rice production, so the savings could be huge. Some African nations are beginning to explore water-saving rice as well.

By 2025, 15–20 million hectares of irrigated rice will experience water scarcity. The "System of Rice Intensification" can increase rice yields by 50-100% while using half as much water.

Information Systems for Farmers

Water management can be greatly improved with creative use of information technologies. In Uganda and India, farmers lacking computers are getting access to the wealth of information on the Internet by calling in their questions to a free telephone hotline called Question Box. The operators, who speak the local language, search for the answers and call the farmers back. Question Box enables poor farmers, whose only communication device may be a village phone, to connect to the wired world for information on weather forecasts, plant diseases, and more. Efforts are underway to create a model for duplicating Question Box; learn more at questionbox.org.

Ecosystem Services

Ecosystem services are of critical importance for adaptation to climate change. Fisheries, forest and woodland products, livestock grazing, floodplain farming, wetlands products, tourism, domestic water supply and storm-surge protection are all dependent on ecosystem services. Free-flowing rivers are more resilient in the face of climate change than their dammed counterparts, while providing a range of ecosystem services (see Chapter 1).

Ecosystem services, if well managed, can increase the resilience of natural and human systems to climate change impacts. For instance, protecting mangroves for coastal defense and floodplain management for flood defense are effective alternatives to building large infrastructure or water-intensive projects.

However, approximately 60% of all ecosystem services are being degraded or used unsustainably.[52] In addition, ecosystem degradation can trigger more disasters and reduce resilience to climate impacts, as well as reducing the ability of ecosystems to sequester carbon. There has been a sharp increase in the occurrence of natural disasters such as floods, droughts, extreme temperatures, and wildfires from 1960 to

Treadle pumps have enabled more than a million Bangladeshi farmers to grow marketable produce. Photo: iDE

Rice paddies at Don Sadam Island, which is threatened by the Don Sahong Dam on the Mekong River. Photo: International Rivers

1989, and an even more rapid increase since 1990. While this trend may not be wholly attributable to climate change, the increase in the frequency and intensity of climate-related hazards does correspond to temperature increase, and is projected to continue even if greenhouse gas emissions were to stabilize. Unless ecosystem management is prioritized and integrated into climate change adaptation and disaster risk management, the poor and their natural resources and livelihoods could become even more vulnerable to climate change impacts.

Many US communities are involved in projects to revitalize their rivers and restore ecosystem services by tearing down dams that are no longer safe or serving a justifiable purpose. In the past 20 years, through the collaborative efforts of a range of stakeholders including Native American tribes, hundreds of dams have been removed from US rivers, opening up habitat for fisheries, restoring healthier water flows, improving water quality, and returning aquatic life to rivers. Fish populations usually recover quickly. In one of the nation's biggest dam removals, the Edwards Dam was removed from the Kennebec River in Maine in 2000. Since then, fish populations have returned in astounding numbers, reviving a recreational fishery that adds $65 million annually to the local economy. In 2007, Portland General Electric blew up the Marmot Dam on Oregon's Sandy River. The river washed accumulated sediment downstream more quickly than anticipated, and Coho salmon swam past the dam the day after it was breached.

Some Latin American cities are establishing watershed trust funds to protect their drinking water supply. For instance, Rio de Janeiro in Brazil collects fees from water users to pay upstream farmers and ranchers US$71 per hectare to protect and restore riparian forests, safeguarding the water supply and preserving wildlife habitat. A public watershed protection fund in Quito, Ecuador, started in 2000 in partnership with the Nature Conservancy, receives nearly $1 million a year from municipal water utilities and electric companies. Quito's water fund has become a model for other Latin American cities.

Using Citizen Science to Save Fisheries in India

By Parineeta Dandekar, South Asia Network on Dams, Rivers and People, Delhi, India

India is second in the world in freshwater fish production. More than 75% of fisherfolk in India depend on freshwater fisheries for their livelihoods. Many millions of Indians depend on rivers for their livelihoods and nutrition; the Ganga Basin alone supports 7-8 million fisherfolk.

Unfortunately, riverine fisheries are one of India's most endangered areas. Water abstractions and dams have led to fisheries collapses in almost all of India's major rivers, severely affecting biodiversity and livelihoods. Fisherfolk, one of the poorest segments of Indian society, have been deeply impacted. In the words of an anguished fisher woman in Maharashtra, "The dam reduced us from being the king of the river, to a slave of this dam."

Though blessed with one of the richest riverine fish gene pools in the world, the contribution of riverine and capture fisheries is declining sharply and many have collapsed, despite having a great potential to grow. Climate change threatens to make the situation much worse. This is especially true for the fragile Himalayan states which are witnessing extreme impacts of climate change on the one hand and unprecedented hydropower development on the other.

Taking Action

Since 2009, tribal communities in over 32 villages in Central India have come together to work on a People's Biodiversity Register, under the Biodiversity Act of India. The People's Biodiversity Register for the Kathani River, for example, revealed that this small river had 64 distinct fish species. The local tribal fishermen had distinct names for all of these species. Following declining fish populations in Kathani, the communities, equipped with their own documentation and studies, voluntarily banned herbal fish poisons, and took an ecosystem approach to fish conservation by banning riparian tree felling, planting trees and conserving fish in riverine stretches or sanctuaries. Fish stocks are gradually improving in the river.

In the Vidarbha region of Central India, which has become infamous for farmer suicides, fisherfolk are getting organized, forming self-help groups and fisheries cooperatives. Tribal fishermen possess in-depth knowledge about fish species, breeding needs, habitats and ecology. With the help of organizations like Bhandara Abhyas Mandal, the groups have started documenting the diversity of fish and aquatic plants. Indigenous fish species found in traditional fish-rearing tanks are being documented. With the help of this knowledge, fish species are being propagated in derelict tanks by creating habitats using indigenous vegetation. Fish yields have increased dramatically following this approach.

Marginalized estuarine fisherfolk cross the Vashishti River in the Western Ghats (Maharashtra, India). Photo: SANDRP

The Indian government is exceedingly weak on protecting riverine fisheries. One of the most urgent first steps is to include the true impacts of dams on fisheries in Environmental Impact Assessments and Management Plans for dams. We also need to adopt a strong law and supporting policies to protect fisheries and local livelihoods; put pressure on dam owners and operators to compensate affected fisherfolk; adopt a national law mandating restorative environmental flows through existing dams, and undertake serious research on fish passes and ladders for Indian conditions and species. Climate change is already affecting distribution and abundance of fish species in several regions. Protecting fish diversity by addressing major issues related to dams will be a strong step in building resilience.

We also need honest and holistic cost benefit analysis of dams – analysis that accounts for the risks from climate change. Currently, the words "climate change" do not feature in environmental governance surrounding India's dams. Underperforming dams and barrages in biodiversity-rich regions need to be decommissioned. Finally, we need more protected and free flowing rivers to appreciate the range of services a healthy river can provide.

A longer version of this article can be downloaded here: http://www.internationalrivers.org/node/7758

Indigenous groups protest during the International Hydropower Association's world congress in Sarawak, Malaysia in May 2013. Photo: SAVE Rivers Network

Conclusion

A river's goods and services lost to a large river engineering project are difficult to retrieve or replicate. While all nations will be impacted by climate destabilization, it is the marginalized and the poor who are most vulnerable to the effects of climate change and the compounding impacts of large river infrastructure projects. Rising temperatures, more frequent extreme weather events, and shrinking water resources will worsen existing problems such poverty, malnutrition, and disease. Members of national governments, academia and industry will need to come together with affected communities and civil society to develop climate-resilient adaptation and mitigation solutions that dramatically cut climate pollution without sacrificing the planet's lifelines upon which we currently depend.

As someone working on climate adaptation and development issues, you are uniquely placed to be the bridge between those who are most impacted by climate change, and the experts and decision-makers who have the resources and information to aid in the development of sustainable adaptation projects and programs.

This guide has laid out a series of actions that citizen's groups can take in order to ensure that climate risks are adequately **understood, assessed,** and **addressed**, before solutions can be found to **adapt** to climate change. The key recommendations are summed up here:

ASSESS:

- Conduct a community-level needs and capacity assessment.
- Help build capacity around climate change topics through research and consultation with climate experts.
- Empower women in the community at all stages of the adaptation process.
- Identify the risks and vulnerabilities, especially for marginalized groups.
- Combine top-down with bottom-up approaches in order to avoid gaps in information.
- Assess the climate risks of existing water infrastructure projects by asking key questions of decision-makers, and promote the development of a Climate Change Assessment for planned projects and programs (for instance at the SEA or project feasibility stage).

ADDRESS:

- Conduct or participate in an options assessment for alternative water and energy projects.
- Lobby decision-makers to mandate integrated planning and policies that combine meeting water, energy and employment needs.
- Promote the "precautionary principle" in the face of climate uncertainty.
- Protect ecosystem services and ensure that if dams are built, an environmental flows plan is developed and implemented.
- Develop ecosystem, livelihood and disaster monitoring systems at the community level.
- Ensure climate-risk management is included throughout the entire project life- cycle.

ADAPT:

- Select and design a sustainable "no-regrets" solution that follows the principles of climate resilience.
- Ensure solutions address the needs of the most vulnerable and do not lead to a maladaptation or compromise existing efforts at adaptation.

Each individual context will differ in terms of the right strategies and the amount of climate information available, but a multitude of online and human resources, including International Rivers staff, exist to help you chart these new waters. To learn more about any of these aspects, follow the links within the guide that we have provided and check out *Key Resources* (Appendix 1) for practical field guides, climate studies, and adaptation institutions with expertise in water resource management. And as always, please let us know if you have any suggestions for improvement, as we continue to develop our resources and support for civil society organizations in this ever-evolving topic.

Appendix 1: Key Resources

ADAPTATION MANUALS:

CARE's Climate Vulnerability and Capacity (CVCA) Handbook on resource and hazard mapping: www.careclimatechange.org/cvca/CARE_CVCAHandbook.pdf

CARE's Participatory Monitoring, Evaluation, Reflection and Learning for Community-based Adaptation Manual: www.careclimatechange.org/files/adaptation/CARE_PMERL_Manual_2012.pdf

Cornell University's Citizen Science Toolkit: www.birds.cornell.edu/citscitoolkit

Global Water Partnership's Toolbox on Integrated Water Resource Management: www.gwptoolbox.org

Rainwater Harvesting Implementation Network's manual on sand dams: www.rainfoundation.org/fileadmin/PublicSite/Manuals/Sand_dam_manual_FINAL.pdf

Tim Magee's A Field Guide to Community Based Adaptation, with downloadable templates and additional resources: www.timmagee.net/field-guide-to-cba

The UK Department for International Development's Sustainable Livelihoods Guidance on the sustainable livelihoods approach. www.eldis.org/vfile/upload/1/document/0901/section1.pdf

World Resources Institute's *Making Adaptation Count: Concepts and Options for Monitoring and Evaluation of Climate Change Adaptation*: www.wri.org/publication/making-adaptation-count

ADAPTATION CASE STUDIES AND EXPERTS:

Adaptation Partnership (individual and community action plans): www.adaptationpartnership.org/blog/activities

Africa Climate Exchange (a knowledge transfer project to facilitate the exchange of climate science and adaptation knowledge, thus far focused on Senegal, Sudan and Ghana): www.afclix.org/elgg

Alliance for Global Water Adaptation, a network of water adaptation professionals: www.alliance4water.org

Climate Adaptation Knowledge Exchange's adaptation case studies: www.cakex.org

Practical Action: www.practicalaction.org

SciStarter's citizen science projects on climate, weather and water: www.scistarter.com

weAdapt (case studies on practical adaptation solutions): www.weadapt.org

Watershed Organization Trust in India, www.wotr.org

ADAPTATION FUNDING OPPORTUNITIES

Climate Funds Update: www.climatefundsupdate.org/listing

IDEAS Energy Innovation Context (Americas only): www.iadb.org/en/news/announcements/2013-06-25/2013-ideas-energy-innovation-contest,10436.html

Terra Viva Grants: www.terravivagrants.org/Home/funding-news/climate-change

ORGANIZATIONS SUPPORTING SMALL-SCALE ADAPTATION PROJECTS

Air and Water Conservation Fund (National Geographic, China only): www.nationalgeographic.com/explorers/grants-programs/gef/china/

Africa Enterprise Challenge Fund (private sector, Africa only): www.global-mechanism.org/en/adaptation-and-mitigation-funds/africa-enterprise-challenge-fund-renewable-energy-and-adaptation-to-climate-technologies-react

Asia Foundation: www.asiafoundation.org/about/grant-guidelines.php

Conservation Food and Health Foundation: www.cfhfoundation.grantsmanagement08.com

Global Greengrants Fund recommendations: www.greengrants.org/our-grants/infomation-for-grantseekers/ and http://www.greengrants.org/programs/areas-of-focus/climate-change/

Greengrants Alliance of Funds: www.greengrants.org/our-community/alliance-of-funds/

Indigenous and Traditional Peoples Conservation Fellowship (Conservation International): www.conservation.org/about/centers_programs/itpp/pages/indigenous_fellowship.aspx

Peace Development Fund: www.peacedevelopmentfund.org/page/programareas

Peer Water Exchange: www.peerwater.org/

UNFCC's Adaptation Fund: www.adaptation-fund.org/

United Nations Trust Fund: www.undesadspd.org/IndigenousPeoples/TrustFund/ApplyforFunding.aspx

WISIONS: www.wisions.net/pages/seps-energy-projects

CLIMATE STUDIES:

Adaptation Learning Mechanism (provides country summaries on observed and projected climate change impacts, national adaptation plans, and relevant strategies): www.adaptationlearning.net

Center for Ecology & Hydrology's Water and Global Change Watch (includes global and basin-specific rainfall, freshwater, and evaporation maps): www.waterandclimatechange.eu

Institute of Development Studies Report, Gender and Climate Change: An Overview: www.bridge.ids.ac.uk/go/bridge-processes-and-publications/reports&id=59217&type=Document

IPCC Fourth Assessment Report, Climate Change 2007: Impacts, Adaptation and Vulnerability: www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html

Middlebury College's student research paper, "Hydropower Vulnerability and Climate Change (offers synopsis of available research of climate change impacts on regional river basins and hydropower generation): www.middlebury.edu/media/view/352071/original

The Nature Conservancy's Climate Wizard (visualizes temperature and precipitation impacts based on IPCC scenarios): www.climatewizard.org

World Bank briefing on hydropower vulnerability, "Addressing climate change-driven increased hydrological variability in environmental assessments for hydropower projects: a scoping study": http://bit.ly/17tg3e6

World Bank's Climate Change Knowledge Portal: www.sdwebx.worldbank.org/climateportal/index.cfm

COMMUNITY MAPPING TOOLS:

Data Basin: www.databasin.org

Making Maps that Make A Difference: www.internationalrivers.org/files/attached-files/makingmaps.pdf

PPgis.net, an open forum on participatory geographic information systems (GIS) and technologies: www.ppgis.net

TerraLook: www.terralook.cr.usgs.gov

Ushahidi: www.ushahidi.com

AGROECOLOGY TOOLS:

Institute for Agriculture and Trade Policy: www.iatp.org/documents/agroecology-and-advocacy-innovations-in-asia

Pesticide Action Network: www.panna.org/science/agroecology/science

Via Campesina has a number of publications on agroecology: www.viacampesina.org/en/index.php/publications-mainmenu-30

Appendix 2: Climate Change Impacts on Rivers and Species

Source: Le Quesne et al. (2010). "Flowing Forward: Freshwater Ecosystem Adaptation to Climate Change in Water Resources Management and Biodiversity Conservation," Water Working Notes 28, World Bank Group, p. 18.

IMPACTS OF CLIMATE CHANGE	ECO-HYDROLOGICAL IMPACTS	IMPACTS ON ECOSYSTEMS AND SPECIES
■ Changes in volume and timing of precipitation ■ Increased evapotranspiration ■ Shift from snow to rain, and/or earlier snowpack melt ■ Reduced groundwater recharge ■ Increase in variability and timing of monsoon ■ Increased demand for water in response to higher temperatures and climate mitigation responses	Increased low-flow episodes and water stress	■ Reduced habitat availability ■ Increased temperature and pollution levels ■ Impacts on flow-dependent species ■ Impacts on estuarine ecosystems
■ Shift from snow to rain, and/or earlier snowpack melt ■ Changes in precipitation timing ■ Increase in the variability and timing of annual monsoon	Shifts in timing of floods and freshwater pulses	■ Impacts on spawning and emergence cues for critical behaviors ■ Impacts on key hydrology-based life-cycle stages (e.g., migration, wetland and lake flooding)
■ Increased temperatures ■ Reduced precipitation and runoff	Increased evaporative losses from shallower water bodies	■ Permanent water bodies become temporary/ephemeral, changing mix of species (e.g., from fish-dominated to fairy shrimp–dominated)
■ Increased precipitation and runoff ■ More intense rainfall events	Higher and more frequent storm flows	■ Floods remove riparian and bottom-dwelling organisms ■ Changes in structure of available habitat cause range shifts and wider floodplains ■ Less shading from near-channel vegetation leads to extreme shallow water temperatures
■ Changes in air temperature and seasonality ■ Changes in the ice breakup dates of lakes	Shifts in the seasonality and frequency of thermal stratification (i.e., normal seasonal mixing of cold and warm layers) in lakes and wetlands	■ Species requiring cold-water layers lose habitat ■ Thermal refuges disappear ■ More frequent algal-dominated eutrophic periods from disturbances of sediment; warmer water ■ Species acclimated to historical hydroperiod and stratification cycle are disrupted, may need to shift ranges in response
■ Reduced precipitation and runoff ■ Higher storm surges from tropical storms ■ Sea-level rise	Saltwater encroachment in coastal, deltaic, and low-lying ecosystems	■ Increased mortality of saline-intolerant species and ecosystems ■ Salinity levels will alter coastal habitats for many species in estuaries and up to 100 km inland
■ Increase in intensity and frequency of extreme precipitation events	More intense runoff, leading to increased sediment and pollution loads	■ Increase of algal-dominated eutrophic periods during droughts ■ Raised physiological and genetic threats from old industrial pollutants such as dioxins
■ Changes in air temperature ■ Increased variability in temperature	Hot or coldwater conditions and shifts in concentration of dissolved oxygen	■ Direct physiological thermal stress on species ■ More frequent eutrophic periods during warm seasons ■ Oxygen starvation for gill-breathing organisms ■ Miscues for critical behaviors such as migration and breeding

Appendix 3: Table of Key Questions for Assessing Climate Risks of River Projects

For communities dealing with planned and existing dams and diversions on their rivers, asking the right questions to project developers and government planners and decision-makers can help guide them evaluate the potential climate risks and the possible impact a project will have on a community's climate resilience. Asking these questions can prompt decision-makers to develop a climate risk assessment to inform SEAs and EIAs, or even reconsider or revise project plans. These questions should be raised at all stages of a project's life cycle.

SOCIAL IMPACTS

<table>
<tr><th>KEY QUESTIONS</th><th>DATA SOURCES NEEDED</th></tr>
<tr><td colspan="2">WATER RESOURCE AVAILABILITY</td></tr>
<tr><td colspan="2">With some dam storage or water diversion projects, water users may experience benefits such as increased reservoir storage in preparation for droughts or greater delivery of water from water-rich regions to arid regions. However, there is also the risk that they may experience diminishing resources during droughts, as well as conflicts between reservoir storage and hydroelectric production. Increasing precipitation in certain areas can bring several benefits, including increased agriculture yields and lengthened growing seasons.[3] However, the risks of variable precipitation rates include the threat of drought and/or floods, poor timing of rains in relation to growing seasons, loss of livelihoods, damage to ecosystem, and reduced reservoir storage.</td></tr>
<tr><td>

How will the project affect the community's access to clean water? What will be the impact on existing sources, including groundwater? Will new sources be provided if existing sources will be compromised?
Does the project take a systemic watershed approach and analyze cumulative impacts of all dams in the basin?
Does the project incorporate management techniques that will limit the disruption of natural flows downstream?
Is the management of the project creating reserves to help provide for local populations in times of drought?
What is the quality of hydrological data? Are projects being planned with changes in precipitation in mind?
Have flood safety measures or drought risk management plans been developed and put in place?
Do relocation sites have sufficient access to natural resources and are there adaptive management plans for high or low precipitation scenarios?

</td><td>

Drought and flood season measurements at gaging stations
Water level measurements at gaging stations
Project SEIAs or master plans
Measurement of water levels in reservoirs at gaging stations
Amount of precipitation measured by national weather offices

</td></tr>
</table>

INTERNATIONAL RIVERS

<table>
<tr><th>KEY QUESTIONS</th><th>DATA SOURCES NEEDED</th></tr>
<tr><td colspan="2">LIVELIHOODS</td></tr>
<tr><td colspan="2">While there may be some benefits from large dams and river engineering projects such as hydropower, irrigation, navigation, and water supply, there is also a high risk that large infrastructure projects can decrease climate resilience and threaten livelihoods because they lead to a loss of cropland and forests, displacement, and damage to fisheries and wetlands.</td></tr>
<tr><td>
■ Are there traditional food systems or livelihoods that have been or may be altered, and are the changes a result of climate change?
■ How are livelihoods or loss of livelihoods considered in the development of the project? Are direct and indirect impacts considered (for example, an indirect impact would be the influx of migratory workers and their demand on local resources)?
■ What are the main effects of climate change for the community and have they been addressed in the project's social impact assessment?
■ What kinds of activities are being carried out in the community to adapt to the changing climate?
</td><td>
■ Household surveys regarding local benefits from the project in terms of economic stimulation, employment, infrastructure, etc.
■ Stakeholder consultation and social impact assessment reports
</td></tr>
<tr><td colspan="2">HEALTH</td></tr>
<tr><td colspan="2">Construction of large reservoirs can increase health risks from a number of waterborne diseases, including schistosomiasis, malaria, and river blindness. Dams also worsen problems of water pollution and water scarcity, and damage ecosystem services, all of which have their own health risks.[4]</td></tr>
<tr><td>
■ Has a health impact study been done? Have local public health agencies been involved?
■ What types of strategies are being proposed or implemented to avoid or mitigate waterborne diseases? What will be the role of local public health agencies?
■ Have the health impacts of a large migratory construction crew on the local population been addressed? (e.g., sexually transmitted diseases)
■ What health services will be provided to deal with health impacts from the project? How are these services being paid for?
■ Will the project have a negative impact on water quality, and if so, what is being proposed to address this issue?
■ Will the project reduce habitat for medicinal plants?
</td><td>
■ Community surveys about local access to healthcare, and strong involvement by local health professionals and agencies
■ Sampling of water sources for waterborne diseases along the river and the reservoir
■ Plans to control the spread of HIV/AIDs and other STDs
■ Budget for building and staffing clinics.
■ Plan to eliminate sources of pollution in the reservoir watershed and upstream.
■ Survey with community health workers to determine species disruption. Plan to restore lost resources in resettlement areas.
</td></tr>
</table>

KEY QUESTIONS	DATA SOURCES NEEDED
GOVERNANCE	
Given the uncertainties of climate change, a governance structure and decision-making process that is flexible, transparent, and participatory will more likely succeed in improving climate resilience.	
■ Have strong local paths of engagement been incorporated in government-led assessment processes? Do they occur early in the project assessment stage and throughout the project development process? ■ Is there a disaster risk management plan and preventive measures in place to deal with droughts and floods? ■ Is there a Cumulative Impact Assessment and does it include climate impacts? ■ Is there an adaptation plan in place to help mitigate the negative impacts of dams on river basin communities under different scenarios? ■ Are there accountability mechanisms in place and a means of enforcement that hold developers accountable for meeting projected water and energy needs without destroying key environmental services? ■ Is an assessment of climate risks required during dam relicensing processes, and is it robust and participatory? Where licenses have been given for perpetuity, will they be re-assessed for climate impacts?	■ Government or financial institutions' policies and laws on participation by project-affected people ■ National legal mechanisms to compensate for appropriation of resources ■ Water and energy development plans. ■ Environmental and/or energy agency mission statements ■ Company sustainability or corporate social responsibility guidelines. ■ National adaptation plans

ENVIRONMENTAL IMPACTS

SOIL EROSION IN WATERSHEDS AND COASTAL DELTAS	
Dam building increases the risk of biodiversity and livelihood loss due to the withholding of nutrient-rich sediments, which can lead to habitat erosion and a reduction of coastal delta productivity. Deltas and areas experiencing more severe floods will see increased erosion.	
■ Does the river basin experience high precipitation and is precipitation expected to increase? (Higher precipitation will mean greater erosion.) ■ What is the extent of erosion in the watershed? ■ How will sedimentation be managed at the proposed or existing dams? ■ What rehabilitation or watershed management projects (such as afforestation or improved farming practices) have been proposed in the watershed? What are their costs and have they been accounted for in project assessments? ■ What are the impacts of the loss of sediment transport on downstream ecosystems and floodplain agriculture?	■ Soil erosion rates (EIAs) ■ Projected flood scenarios and precipitation models

<table>
<tr><th>KEY QUESTIONS</th><th>DATA SOURCES NEEDED</th></tr>
<tr><td colspan="2">RIVER FLOWS</td></tr>
<tr><td colspan="2">Building large dams can mean storage for irrigation, domestic or industrial use, and possibly some flood control. However, the risks include changes to the magnitude, duration, timing, and frequency of high and low flows, which can devastate the migration and spawning of fish species and the productivity of riparian agriculture.</td></tr>
<tr><td>

How will climate change affect a river's natural flow (e.g. increase or decrease magnitude, duration, timing, and frequency)? How have expected precipitation and flow changes from climate change been addressed in plans for environmental flows?
How will the project change the river's natural flow and water quality, and how will this alter or disrupt surrounding river vegetation, floodplain agriculture, and fisheries?
What will be the economic impact of losses caused by altered flows? Are these costs fully accounted for in the cost-benefit analysis for new river infrastructure?
For run-of-river projects, how long will the reservoir be able to store flows? How will the storage time of water affect aquatic life and other natural processes?
Have food security impacts been quantified? Has this information been vetted by the local people?
What is the plan for calculating and incorporating environmental flows into the design of a project or into the operation of existing projects?
What ecosystem values are the environmental flows plan intended to protect or preserve?
What is the plan for environmental flows in times of drought?
What role will local communities be allowed to play in the maintenance and refinement of the environmental flows plan? Are there transparent mechanisms for monitoring that the public can use?
How will the environmental flows plan be enforced?
For transboundary rivers, will an environmental flows plan be developed between all nations that share the river?

</td><td>

Seasonal storage, annual storage, and multiple year storage data (project design documents)
River basin management plans and EIAs
Hydrology data for local rivers

</td></tr>
</table>

<table>
<tr><th>KEY QUESTIONS</th><th>DATA SOURCES NEEDED</th></tr>
<tr><td colspan="2">DEFORESTATION</td></tr>
<tr><td colspan="2">Building new large water and energy projects in heavily forested areas often brings large-scale logging to make way for the project and/or transmission lines. The negative effects of deforestation can include harm to the ecology and hydrology of rivers, loss of species habitat, compromised water quality, increased flood risks, and loss of nutrients from terrestrial sources. In addition, forests act as important carbon sinks in the global carbon cycle, and deforestation reduces those important sources of carbon regulation. Fragmentation of forests, reduced transpiration, and reduced soil water availability combined with warming temperatures from climate change can also contribute to drier conditions and the potential for more wildfires.</td></tr>
<tr><td>Does the project account for GHG emissions of associated deforestation?
In the case of a project constructed as a low carbon energy option, will deforestation turn the project into a net carbon emitter? Does this disqualify the project from receiving clean energy or mitigation funding?
How will current climate change trends worsen problems caused by deforestation?
What impacts will climate change and deforestation have on local livelihoods and resource availability? What measures are in place to address these impacts?</td><td>Project's projected rates of deforestation (EIAs)
UN Food and Agriculture Organization national data, remote sensing data, measurements of carbon stocks using default values or ground-based measurements (tree height, rate of deforestations).[5]
Data on climate change interaction with deforestation impacts, such as moisture loss (regional studies)</td></tr>
<tr><td colspan="2">GREENHOUSE GAS EMISSIONS</td></tr>
<tr><td colspan="2">All water and energy projects will have a carbon footprint during construction, and for some, during operation as well, especially if you consider the materials used in building and operating the project. Dams in particular have the potential to add to global warming through their methane emissions, which is a greenhouse gas (GHG) that is 25 times more potent than carbon dioxide. Dams in the tropics are particularly polluting when it comes to GHG emissions. Data for GHG emissions is limited but may be available if the project is participating in the Kyoto Protocol's Clean Development Mechanism.</td></tr>
<tr><td>Are emissions being accounted for in the full life cycle of the project, including construction, deforestation, and materials used?
For dams, are degassing, ebullition, and diffusion at the reservoir surface, turbines and spillways and immediately downstream all accounted for as part of the GHG measurements?
For proposed dam projects, what GHG emissions research is available for similar reservoirs in the same region?
Are decommissioning costs included for dam projects with short life spans and high GHG emissions (since even non-functioning reservoirs will continue to emit GHGs)?</td><td>Emissions calculations for above-water biomass, reservoir surface, turbines and spillways, and loss of living forest (sources and sinks) in EIAs or research studies.
Projected emissions from project construction in EIAs or research studies.</td></tr>
</table>

ECONOMIC AND SAFETY IMPACTS

KEY QUESTIONS	DATA SOURCES NEEDED
ECONOMIC FEASIBILITY	
An increase in extreme weather events and changes in climate and precipitation will have varying impacts on a project's long-term economic viability, as well as adding to project costs for managing and mitigating climate-related disasters.	
■ Does the project have a disaster risk management plan and is it funded? Which government agency will be responsible for it? ■ Are the costs of potential impacts from climate change on project operation (such as water shortages during times of drought) incorporated into overall project costs? ■ Is dam decommissioning one of the options to deal with poor project economics? ■ Before new projects are planned, have existing projects been assessed for reoperation or rehabilitation?	■ Risk management plans ■ Cost-benefit analysis and economic feasibility plans
ELECTRICAL OUTPUT	
Greater precipitation could lead to an expansion of electrical power generation for hydropower dams, while greater hydrological variability and decreased rainfall could lead to decreased or a complete loss of electrical power generation and subsequent impacts on local and national economies. Climate-related disasters could also affect the electrical output of other types of energy projects and energy grids, most often leading to blackouts.	
■ How will countries compensate for a potential decrease or a complete loss of electrical power generation? What alternative back-up energy systems exist in-country if an energy project is not generating power? ■ What are the electrical output differences between the rainy and dry seasons? ■ Does the project's economic analysis take into account climate change scenarios?	■ National energy and disaster risk management plans ■ Precipitation data (regional climate models and studies) ■ Past records of hydropower production
STRUCTURAL INTEGRITY & DAM SAFETY	
Dams and levees can provide protection from flooding if well managed. However, failure to adapt water management strategies to a changing climate provides the potential for dams to break under more extreme floods, as in places where Glacial Lake Outburst Floods (melting of ice dam from water pressure) is a real risk. Building large infrastructure projects for climate adaptation in seismic zones can also increase the risk of structural failure, with negative downstream consequences.	
■ Are different climate change scenarios (e.g. glacial outbursts, flooding, high intensity precipitation, silt inflows, downstream drought, and subsidence) considered in the safety assessments for and design of the dam? ■ Do water management and dam safety plans include climate change considerations? ■ Are downstream impacts assessed and accounted for?	■ Streamflow and climate data for predicting flood hazards ■ Paleo and historic flood data for understanding long term flood trends

Appendix 4: Supplemental Work Sheet for Dam-Affected Communities

All the regions of the world will be impacted by climate change. Solutions to the combined impacts of dams and climate change will need to address the local context, including local geography and weather, political and economic realities, and socio-cultural conflicts and conditions.

The purpose of this supplemental work sheet is to help community members, activists and civil society groups begin to assess and address the climate risks to dams and dammed rivers that are particular to their regions. Facilitators can modify and adapt this work sheet according to your training needs. You can download this work sheet at www.internationalrivers.org/node/8104

HOW TO USE

1. Create a locally specific version of the work sheet in a new document. Include any case studies from the guide that might be useful. Information on specific river basins may be found here: www.waterandclimatechange.eu. Information on dams can be found here: www.internationalrivers.org

2. With the guide as a reference, work through each question through discussion and activities. Field guides for specific community-level assessments can be found here: www.timmagee.net/field-guide-to-cba and http://www.careclimatechange.org/cvca/CARE_CVCAHandbook.pdf

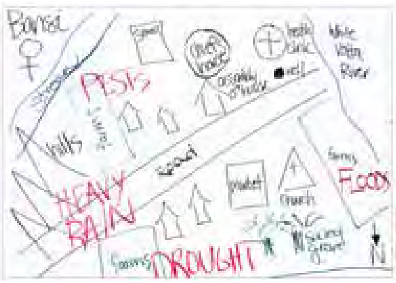
3. *Optional:* Depending on your group, consider printing out copies of the glossary, *Appendix 1: Key Resources*, and *Appendix 3: Key Questions for Assessing Climate Risks of River Projects* for participants.

(BEGIN WORK SHEET)

A. Local community-based assessments

Directions: With just the knowledge you have from your own experience and the experience of those around you, answer the following questions.

1. *What local climate impacts and extreme weather events are you seeing in your region? With the group, draw a hazards map of your watershed (this example from CARE).*



2. *What are key community-wide events and activities that typically happen throughout the year? As a group, develop a calendar for the year that includes: holidays and festivals; planting, harvest and fishing seasons; periods of typical resource scarcity, human migrations, rainy and dry seasons, flooding season, fire season, etc. (This activity will help identify periods of stress and changes in seasonal activities.)*

3. *What are major past events such as natural disasters and changes in land use, land tenure, food security, and/or social or political transitions that have occurred in your community's memory? (This will help to identify more long-term trends.)*

4. *How are weather-related hazards impacting your livelihoods, health and basic needs over time? (This will help assess some of the vulnerabilities of your community.)*

   Food:

   Water:

   Income generation:

   Health:

   Energy use:

   Education:

   Other areas:

5. *What are some projects or programs that already exist that are helping your community deal with these problems? Please state whether these projects or programs are being run by local/ national government, NGOs or communities themselves.*

B. Climate risks of dams to communities

Directions: Go through the Key Questions in Appendix 3 and use them to assess the climate risk of the project(s) that are affecting your community or region.

1. *At what stage(s)* are the projects? Circle the stage.*

   Project name:
   Planning (SEA, water/energy blueprint, etc.) / Project identification / Feasibility studies / Project design / EIA / Site preparation / Under construction / Completed, monitoring & evaluation / Relicensing / Decommissioning or removal / Rehabilitation

   Project name:
   Planning Stage: (SEA, national water/energy plans, etc.) / Project identification / Feasibility studies / Project design / EIA / Site preparation / Under construction / Completion, monitoring & evaluation / Relicensing / Decommissioning / Rehabilitation

** Suggestions for what to do at different project stages can be found starting on page 24 of International Rivers' "Dams, Rivers, and Rights – An Action Guide for Communities," which may be a useful reference for subsequent activities. See: www.internationalrivers.org/node/4156.*

2. *What are some of the risks <u>to community resilience</u> from these projects? If you are unsure, make a note of it and mark it for further research or consultation with a regional expert.*

   Water resource availability:

   Local economy:

   Income generation:

   Energy access:

   Food security:

   Health and safety:

   Community governance and cohesion:

3. *What are some of the main climate risks <u>to the projects</u>?*

   Soil erosion and sedimentation:

   River flow:

   Economic feasibility:

   Reduced electrical output:

   Structural integrity and dam safety:

4. *Referring to the Key Questions in Appendix 3, which questions are most important to you and for which you would want answers?*

   <u>SOCIAL IMPACTS</u>

   <u>ENVIRONMENTAL IMPACTS</u>

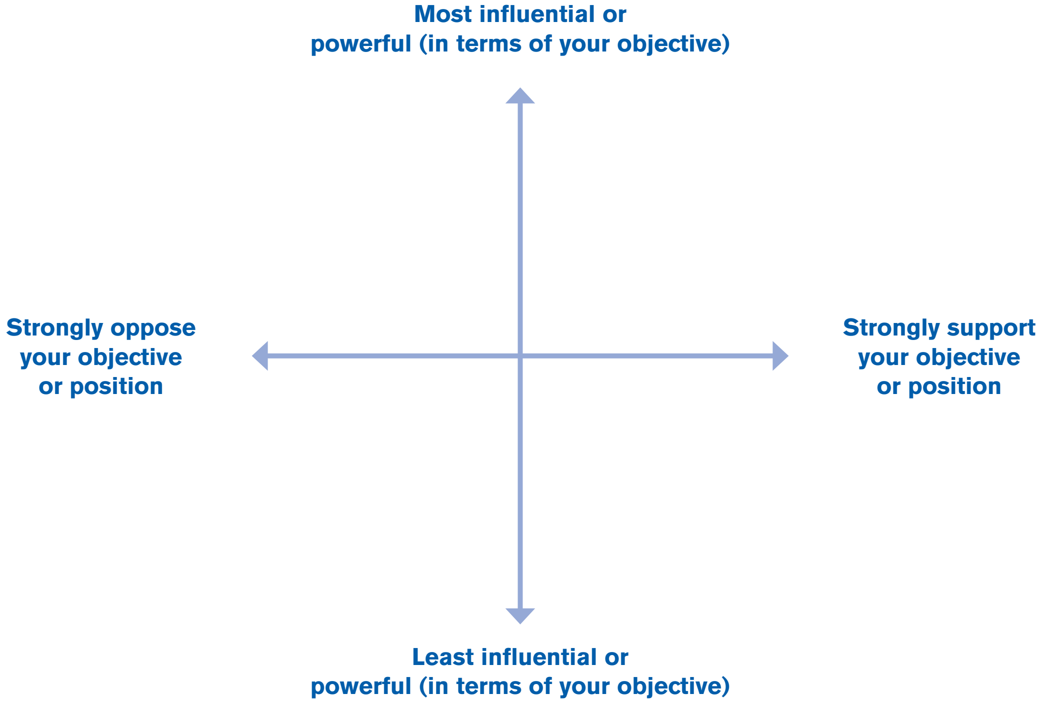
   <u>ECONOMIC AND SAFETY IMPACTS</u>

5. *Who in government, industry and/or civil society can you contact regarding these questions?*

C. What to do next

Directions: Use the following activities to determine who might be sympathetic and willing to talk to you, and what strategies you might undertake to move your community or region towards greater climate resilience. Civil society groups such as NGOs are sometimes better positioned than government or academic institutions to help communities undertake adaption activities, while also being a bridge among community members, decision-makers and the media.

1. *Develop a "power map" of all the relevant national and regional level organizations (governmental and nongovernmental) on the graph below. Think about their level of influence regarding the dam project and river management, and whether these actors have a mandate to address climate change.*



2. *Based on this power map, brainstorm some immediate (say, within one month) and long-term (within the next few months) strategies with clear targets you can take to move your communities or regions toward greater climate resilience. Below are some ideas for possible follow-up strategies:*

   - Conduct in-depth awareness-raising and mapping activities around vulnerability, capacity, and needs with local communities.
   - Take photos and use satellite imagery (if available) to document climate- and dam-related disasters, and share these with decision-makers and the media.
   - Mobilize communities and resources to plan and develop local adaptation projects that increase community climate resilience, protect ecosystems and sustainably manage resources. Assist government and public adaptation agencies that are already developing and deploying climate smart responses and adaptation solutions.
   - Write to decision-makers with unanswered Key Questions regarding river projects that will affect or are affecting the community.
   - Lobby the government to improve the decision-making and regulatory framework to increase public participation, transparency, sound science, and the kind of development that meets the needs of the most vulnerable.

A. Short-term strategies:

Barriers:

What do you need to overcome these barriers?

B. Long-term strategies:

Barriers:

What do you need to overcome these barriers?

Endnotes

1 See for example the Millennium Ecosystem Assessment by the UN: www.millenniumassessment.org/en/index.html
2 Showers, K. (2009) "Congo River's Grand Inga hydroelectricity scheme: linking environmental history, policy and impact," *Water History*, 1.1: 31-58.
3 *Turn Down the Heat: Why a 4°C Warmer World Must be Avoided*, Potsdam Institute for Climate Impact Research and Climate Analytics, World Bank, 2012, www.climateanalytics.org/publications/turn-down-heat-why-4%C2%B0c-warmer-world-must-be-avoided.
4 Magee, T. *A Field Guide to Community Based Adaptation*, Routledge. 2013.
5 Palmer, M. and Allan, J. D. (2006) "Restoring Rivers," *Issues in Science and Technology.*
6 Le Quesne, T. et al. (2010). "Flowing Forward: Freshwater Ecosystem Adaptation to Climate Change in Water Resources Management and Biodiversity Conservation," *Water Working Notes* 28, World Bank Group, p. 8.
7 Poff, N. and Matthews, J. (2013). "Environmental Flows in the Anthropocene: Learning from the Past to Project the Future?" *Environmental Sustainability* (in print).
8 "Big Facts: Impacts on Water," CGIAR Research Program on Climate Change, Agriculture and Food Security. www.ccafs.cgiar.org/bigfacts/impacts-on-water.
9 Le Quesne 2010, p. 15.
10 Palmer, M. "Interview: Climate Change, Rivers and Dams – We're in Hot Water," *World Rivers Review,* International Rivers, 8 September 2013.
11 "The Water Cycle: Snowmelt Runoff." United States Geological Survey. www.ga.water.usgs.gov/edu/watercyclesnowmelt.html.
12 Schneider, A-K. "Dam Boom in Himalayas Will Create Mountains of Risk," *World Rivers Review*, International Rivers, 2 March 2009.
13 de Wit, M. and Stankiewicz, J. (2006) "Changes in Surface Water Supply Across Africa with Predicted Climate Change," *Science*, 311.5769: 1917-1921.
14 McCully, P. *Silenced Rivers: The Ecology and Politics of Large Dams*, Zed Books, 2001, p. 40
15 *Climate Change 2001: Impacts, Adaptation and Vulnerability,* Working Group II, Intergovernmental Panel on Climate Change, 2001, www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=384.
16 Lima, I. B. T. et al. (2008) "Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective," *Mitigation and Adaptation Strategies for Global Change*, 13.2: 193-206.
17 Binstock, J. et al. (2013) *Dams in a Changing Climate: Developing Climate Impacts Assessments for Proposed Dam Projects,* Capstone project for Masters in Public Policy, UCLA Luskin School of Public Affairs.
18 Matthews, J. and Wickel, A. J. (2009). "Embracing uncertainty in freshwater climate change adaptation: A natural history approach," *Climate and Development,* 1.3: 269–279.
19 Binstock, J. et al., 2013. Interview with Shripad Dharmadhikary. 12 February 2013.
20 *Women at the Frontline of Climate Change: Gender Risks and Hopes,* United Nations Environment Programme, 2011, www.unep.org/publications/contents/pub_details_search.asp?ID=6230.
21 Le Quesne 2010, p. 28.
22 Le Quesne 2010, p. 16.
23 Wingspread Conference on the Precautionary Principle, 1998, www.sehn.org/wing.html
24 Beilfuss 2012.
25 Munang et al. (2013). "The role of ecosystem services in climate change adaptation and disaster risk reduction." *Current Opinion in Environmental Sustainability*, 5.1: 47-52.
26 2007 Brisbane Declaration, see www.watercentre.org/news/declaration.
27 Poff and Matthews, 2013.
28 Matthews and Wickel, 2009.
29 "Preparing for Floods," Practical Action, www.practicalaction.org/preparing-for-floods-1.
30 Beilfuss, R., *A Risky Climate for Southern African Hydro,* International Rivers, September 2012, www.internationalrivers.org/node/7673.
31 "Climate Resilience Framework," ISET International, www.i-s-e-t.org/projects-and-programs/climateresilienceframework.
32 "Communities appreciate early flood warning," *The Third Pole*, 22 July 2013, www.thethirdpole.net/communities-appreciate-early-flood-warning.
33 Matthews and Wickel, 2009.
34 *Rainwater Harvesting: A Lifeline for Human Wellbeing*, United Nations Environment Programme and Stockholm Environment Institute, 2009, www.unwater.org/downloads/Rainwater_Harvesting_090310b.pdf.
35 Thakkar, H., *Water Sector options for India in a changing climate,* South Asian Network on Dams, Rivers and People, March 2012, www.sandrp.in/wtrsect/Water_Sector_Options_India_in_Changing_Climate_0312.pdf.
36 Lobo, C. (2010). *Participatory Net Planning: A Practitioner's Handbook,* Watershed Organization Trust.
37 World Development Indicators, World Bank, www.data.worldbank.org/data-catalog/world-development-indicators
38 *Climate Risk and Adaptation in the Electric Power Sector*, Asian Development Bank, July 2012, www.adb.org/publications/climate-risk-and-adaptation-electric-power-sector.pdf.
39 "Seeing the Light: Adapting to climate change with decentralized renewable energy in developing countries." International Institute for Sustainable Development & Climate Change Knowledge Network, 2004, www.iisd.org/cckn/pdf/seeing_the_light_dre.pdf.
40 "Diminishing Returns from Large Hydro," South Asian Network on Dams, Rivers and People, November 2012, www.sandrp.in/HEP_Performance/Diminishing_Returns_from_Large_Hydro_Nov_2012.pdf.
41 Farrell, D., Remes, J. and Charles, D. 2008. *Fueling Sustainable Development: The Energy Productivity Solution,* McKinsey Global Institute.
42 "The Power of Negawatts," International Rivers, January 2009, www.internationalrivers.org/files/attached-files/energyfactsheet.pdf.
43 Enkhbayar, S. (2011). "Development and Climate Change Issues in the Post-2012 Framework: The Northeast Asian Context," ERINA Report.
44 Fleshman, M. "Laying Africa's roads to prosperity," *Africa Renewal*, United Nations, January 2009, www.un.org/africarenewal/magazine/january-2009/laying-africa%E2%80%99s-roads-prosperity.
45 Boyle, G., Krishna R, J., Myllyvirta, L, and Pascoe, O. (2012). *Endangered Waters: Impacts of coal-fired power plants on water supply*, Greenpeace, www.greenpeace.org/india/Global/india/report/Endangered-waters.pdf
46 Halim, N, "Agriculture – Meeting the Water," *Water Challenges and Solutions*, 25 July 2010, www.globalwater.jhu.edu/magazine/article/agriculturemeeting_the_water_challenge
47 Taylor, J. "Agroecology could help green SA agriculture," *Engineering News,* 17 August 2012. www.rainharvest.co.za/2012/08/agroecology-could-help-green-sa-agriculture-reduce-water-use
48 Nhan, D. K. et al. (2012). "Rice production response and technological measures to adapt to salinity intrusion in the coastal Mekong delta," Mekong Program on Water, Environment and Resilience (MPOWER).
49 Nhan, D. K. et al., 2012.
50 Brown, L. "Feeding Everyone Well: Raising Water Productivity," *Eco-Economy: Building an Economy for the Earth*, 2001, www.earth-policy.org/books/eco/eech7_ss4.
51 "Treadle Pumps," iDE, www.ideorg.org/ourtechnologies/treadlepump.aspx.
52 Munang et al., 2013.

Fast Facts

An estimated **260 river basins** are shared by two or more countries, making conflicts over scarce water resources, as well as opportunities for cooperation, a major theme for the 21st century.[1]

About **170 cubic kilometers** of water evaporates from the world's reservoirs every year, more than the total amount of freshwater consumed by all human activities.[2]

By 2025, **15–20 million hectares** of irrigated rice will experience some degree of water scarcity.[3]

Water supplies from inland glaciers and snow cover are projected to decline in the 21st century. Regions that depend on melt water from major mountain ranges contain **one-sixth** of the world's population – most of whom are poor.[4]

A hydropower plant can use from **15,000 to 68,000 liters** of water per megawatt hour generated. To put this into perspective, a nuclear power plant uses about 2,650 liters per megawatt hour, and coal around 1,900. Rooftop solar and wind turbines use virtually no water.[5]

By 2050, **climate change will increase extreme drought**, especially in the subtropics and low- and mid-latitudes. Increased water stress will impact land areas twice the size of those areas that will experience increased water availability.[6]

The area of hyper-arid land increased by **100%** between the 1970s and 2000s.[7]

From 1999-2008, floods affected almost **one billion** people in Asia, **28 million** in the Americas, **22 million** in Africa and **four million** in Europe.[8]

By 2080, **20% of people** will live in areas with increased flood risk.[9]

Populations of freshwater species declined by **50%** between 1970 and 2000.[10]

Global mean sea level is rising at a rate of 3 millimeters (mm) per year. Mangroves build **1-10 mm of soil each year,** which should enable them to adapt to rising sea levels. Mangroves help protect us against coastal hazards such as waves and storm surges. But in dammed rivers, mangroves are deprived of incoming silts and may succumb to rising seas.[11]

Sand dams have been successfully constructed in Kenya, Ethiopia, Angola, Zimbabwe, Japan, India, Thailand, the U.S. and Brazil, benefiting **thousands of people** by providing sustainable, low-cost rainwater harvesting. In two years, the Utooni Development Organization helped to build **1,528 sand dams** in arid and semi-arid areas of Kenya's Rift Valley and eastern region.[12]

Treadle pumps use pedal power to suck water up from wells up to 7.5m deep at a rate of up to **18m³ per hour** – that's six times more water than from a traditional hand pump.[13]

NOTES

1 Black, M. and King, J. *The Atlas of Water: Mapping the World's Most Critical Resource,* 2nd ed. Earthscan, 2009.
2 McCully 2001.
3 Bouman, B. A. M. et al. *Water Management in Irrigated Rice: Coping with Water Scarcity,* International Rice Research Institute, 2007.
4 Bates, B. C. et al. (2008). "Climate Change and Water," Intergovernmental Panel on Climate Change.
5 Reardon, S. "Thirsty clean energy may add to water stressed world," *New Scientist*, 19 July 2013.
6 Bates et al. 2008
7 Black and King, 2009.
8 *Women at the Frontline of Climate Change: Gender Risks and Hopes,* United Nations Environment Programme, 2011, www.unep.org/publications/contents/pub_details_search.asp?ID=6230.
9 Black and King, 2009.
10 Ibid.
11 McIvor, A. et al. (2013) "The response of mangrove soil surface elevation to sea level rise," *Natural Coastal Protection Series: Report 3*, Cambridge Coastal Research Unit Working Paper 42. Published by The Nature Conservancy and Wetlands International, www.coastalresilience.org/science/mangroves/surface-elevation-and-sea-level-rise.
12 Esipisu, I., "'Sand dams' store water for dry season in semi-arid Kenya," *The Christian Science Monitor,* 22 February 2013.
13 "Irrigation," Practical Action, www.practicalaction.org/irrigation-techniques.

For river-dependent communities, large dams and diversions in combination with climate change can bring serious risks to their ability to adapt to climate change. This guide helps civil society groups that work with vulnerable groups to understand and address the particular risks they face from climate change and river-infrastructure projects, and points to sustainable alternatives that promote climate resilience in their river basins.

INTERNATIONAL
RIVERS
people • water • life