ADAPTING WATER MANAGEMENT TO CLIMATE CHANGE

A policy brief for central governments in developed and developing countries, sub-sovereign national bodies, universities and research institutes, community organisations, banks and private investors, aid donors, multilateral financial institutions, UN agencies and other international organisations.

Church of Sweden

Centre for Climate Science and Policy Research

SMHI

KOOPERATION UTAN GRÄNSER

SWEDISH WATER HOUSE

SIWI

VISKOGEN

Note to the Reader:

This Policy Brief was written as a joint effort of the Cluster Group in Climate, Water and Vulnerability hosted by the Swedish Water House (SWH). Cluster Groups are networking initiatives for Swedish organisations and competence in water management and related fields such as economics, environment, gender, climate science, governance, ecosystem management and sanitation. SWH Cluster Groups are small, manageable interdisciplinary networks established around a water-related theme to increase and advance understanding, and to link with ongoing international processes and networks.

The Cluster Group in Climate, Water and Vulnerability includes representatives from the following organisations: Centre for Climate Science and Policy Research, Church of Sweden, GeWa Consulting, Linköping University, Stockholm University, Swedbio, Swedish Cooperative Centre, Swedish Environmental Protection Agency, Swedish International Development Cooperation Agency, Swedish Meteorological and Hydrological Institute, Swedish Society for Nature Conservation, Swedish University of Agricultural Sciences, Vi Agroforestry Programme, and World Wide Fund for Nature.

Photo: Getty Images

How to Cite

Wilk, J. and Wittgren, H.B. (eds). Adapting Water Management to Climate Change. Swedish Water House Policy Brief Nr. 7. SIWI, 2009.

Design and production by Britt-Louise Andersson, SIWI
Cover Photo: Alastair Morrison, SIWI

Table of Contents

Printed by Trosa Tryckeri, Trosa, Sweden. The printing process has been certified according to the Nordic Swan label for environmental quality. For electronic versions of this and other SWH publications, visit www.swedishwaterhouse.se.

Photo: Manfred Matz

Adapting Water Management to Climate Change

"The older folk told stories of how Rain, Sun and Wind went a-wooing Earth, Sister of Moon, and it was the rain that carried the day, and that was why Earth grew a swollen belly after being touched by rain"

Ngugi Wa Thiong'o in 'Petals of blood'

Societies have always had to cope with variable natural conditions. This coping with nature often implies adaptation of whole societies, or at least a large fraction of their technologies, to actual water conditions. Nomadic people migrate seasonally to find water and grazing for their herds. Since ancient times, agricultural civilizations have invented techniques for water storage, transfer and irrigation. Embankments such as levees and dikes are constructed, or lakes lowered, to protect agricultural land, cities or whole countries from flooding.

It is a demanding task for any society to cope with historically known variations in rainfall frequency and intensity, river runoffs, and fluctuating sea levels. When factoring in population growth and increased urbanisation, often in flood-prone areas along coasts or in river valleys, the task becomes even more difficult, particularly in poor regions of the world.

Good water management is a much broader issue than supply of freshwater to thirsty populations. Ecosystems and biodiversity, agriculture and food security, land use and forestry, human health and sanitation, settlements and infrastructure, industry and energy all depend on good water management. The primary purpose of this policy brief is to suggest options that promote water management strategies that are already viable in terms of coping with present problems, and which will become even more urgent when projected climate change impacts are taken into account. Such strategies are sometimes referred to as 'no regret' strategies, meaning that they are good investments even when recognising the large uncertainties regarding the future climate.

As a background, we present a general overview of observed and projected impacts of climate change on water resources, as summarised by IPCC,[7] and an overview of the key concepts of adaptation and vulnerability to climate change, including specific examples of adaptation strategies now in practice. However, it is not enough to point out 'good examples'. Good examples all work in local contexts that influence and dictate their success. The sustainability of such examples, including their potential to disperse to other regions, is often hampered by barriers of different kinds. Overcoming barriers may be the most important function of policies, whether they are local or global. But modifying successful adaptation examples to local pre-conditions – whether cultural, institutional or climatic – is also essential. Therefore, some observations regarding barriers to implementation, maintenance and diffusion of adaptation measures are presented.

Photo: Alastair Morrison, SIWI

Water Resources in a Changing Climate

"Water and its availability and quality will be the main pressures on, and issues for, societies and the environment under climate change" [7]

Observed climate change impacts

During the 20th century, a tendency towards more widespread droughts has been observed in many large regions such as the Sahel, southern Africa, Central America and south Asia. Droughts aggravate drylands, areas inhabited by 34 percent of the world's population and home to eight of the world's 25 identified biodiversity hotspots.[26]

At the same time, observations and model calculations show that the frequency of heavy rainfall events has increased over most land areas in the late 20th century. During the 10-year period 1996-2005 the number of great inland flood catastrophes was twice as large, per decade, as between 1950 and 1980, while related economic losses were five times higher.[21] Socio-economic factors such as economic growth and increases in population in vulnerable areas, along with changes in land-use, are major reasons for the increase in the adverse effects from floods, but since damages have grown more rapidly than population or economic growth, other explanations must also be considered, including climate change.[25]

Since the 1960s, snow cover has decreased in most regions, particularly in the spring and summer, and increasing rates of mass loss have occurred on the majority of glaciers and ice caps. The decrease in water storage in glaciers and snow cover, together with shifts in the amplitude and timing of runoff in glacier- and snowmelt-fed rivers, affect more than one-sixth of the world's population living in the impacted river basins.[31]

Also other water-related trends, such as decreasing groundwater levels and increasing water erosion and sediment transport, have been observed globally. These phenomena, however, are primarily consequences of increased groundwater pumping and anthropogenic land-use changes, respectively, and there is not enough data to provide evidence for possible impacts of climate change. Nevertheless, these changes significantly increase vulnerability to climate change.

Projected climate change impacts

Increased frequency of heavy rainfalls is likely to affect many areas of the world, leading to a higher risk for rain-generated floods. In areas where much of the winter precipitation currently falls as snow, climate warming will result in changes in the seasonality of river flows, with increasing winter flows and decreasing spring flows in several mountainous areas. In rivers draining glaciated regions, particularly in the Asian high mountain ranges and the South American Andes, this shift may be further aggravated by glacier melting. In the short term, glacier melting would lead to increased river flows, but then

the contribution would gradually fall. As a consequence, the hundreds of millions of people who depend on glacial melt water from the Andes, Hindu Kush and Himalayas for their dry-season water supply, will face an increased drought risk.[6]

Overall, the proportion of land in extreme drought at any one time is projected to increase, and many semi-arid and arid areas (e.g., the Mediterranean Basin, western USA, southern Africa and north-eastern Brazil) are particularly exposed and may suffer a decrease of water resources due to the impacts of climate change. Prolonged drought also reduces groundwater recharge, so levels will progressively be lowered.

In addition to quantitative impacts, climate change will have water quality implications. Higher temperatures are likely to affect water quality in lakes through increased thermal stability, which inhibits water circulation. This results in reduced oxygen concentrations and an increased release of phosphorus from bottom sediments. The projected increase in rainfall intensity is expected to lead to increased erosion and to enhanced transport of pollutants. More frequent rainstorms will also overload the capacity of sewer systems and wastewater treatment plants more often. In semi-arid and arid areas, climate change is likely to increase salinisation of shallow groundwater due to increased evaporation and water uptake from vegetation. In coastal areas, rising sea levels may have negative effects on stormwater drainage and sewage disposal, and adversely affect groundwater resources through saltwater intrusion into coastal freshwater aquifers.

In general terms, the projected impacts of climate change on water resources are a continuation of the impacts that have already been observed. At the same time, there are uncertainties of various magnitudes associated with the projections. The findings of several global models should be examined to reduce this uncertainty, especially in regard to regional or local effects. A very robust finding appears to be that warming will lead to changes in the seasonality of river flows in areas where much of winter precipitation currently falls as snow. On the other hand, the projections of future rates of sea level rise currently carry large uncertainties.

Box 1: Melting glaciers in the Himalayas[16]

The water resources from the greater Himalayan region feed ten of the largest rivers in Asia. Approximately 1.3 billion people live in these river basins, which also contain seven megacities. The contribution of snow and glacial melt to these major rivers ranges from 2 to 50 percent. The dependence on the Himalayan region is even larger in the dry season, with rivers such as Ganges and Indus getting 70 percent of their flow from snow and glacial melt in the seasons before and after the summer monsoon.

Climate warming has been greater than the global average in the Himalayas, and Himalayan glaciers are receding faster than the global average.[15] If this trend continues, the base-flow in the rivers may initially increase. But when reservoirs of snow and ice continue to decrease, the variability of downstream runoff will increase and the base-flow will become substantially reduced.

These changes will seriously affect the livelihoods of the people in the river basins who depend on glacial melt from the 16,000 Himalayan glaciers for their domestic and agricultural water supplies and for other ecosystem services such as fisheries. For instance, 500 million people depend on the Yangtze river for their domestic water. The Yangtze, also a crucial supplier of water to Chinese industry and agriculture, experienced its lowest upper reaches flow since the 1920s in 2006.

It is no exaggeration to state that the present rapid economic development in India and China may be severely impacted by a continuation of the present climate trends. Adding political conflicts over water resources, in an already conflict ridden region, makes the greater Himalayan region a crucial target for international climate adaptation endeavours.

Photo: Getty Images

Adaptation and Vulnerability to Climate Change

"The significance of climate change ... lies in its interactions with other sources of change and stress, and its impacts should be considered in such a multi-cause context." [7]

Adaptation concepts and options

Adaptation to climate change can consist of strategies which specifically take climate change and variability into account (*planned adaptation*) or those with goals that are not specifically climate related, but that improve resilience to climate change as an additional effect (*autonomous adaptation*). Autonomous adaptation is most common in developing countries where daily needs are acute and future climate change is a distant concern. Examples of autonomous adaptation include: reviving interest in traditional water harvesting systems to supplement household water supply and irrigation practices; restoring defunct or poorly maintained irrigation facilities to improve water efficiency and equity of access, and; maintaining and establishing wetlands to trap nutrients and provide food and fodder for people and livestock.

The most successful and sustainable climate change adaptation strategies will be those that can simultaneously reduce vulnerability toward a variety of stressors including present climate variability and future climate change, globalisation, urbanisation, environment degradation, disease outbreaks, and market uncertainties. It has been repeatedly stated that water is intrinsically interlinked with the well-being and resilience of ecosystems and human societies. Several of the *Millennium Development Goals* have a direct or indirect relation to water. Many options for adaptation of water management to climate change can therefore be designed to achieve urgent environmental and social objectives related to present climate conditions, such as protection of water sources during flooding conditions and water conservation practices in drought-prone areas. Furthermore, conditions other than climate change are often more important in exerting stress on livelihoods, particularly in low-income countries. Examples include: lack of education, poverty, limited market access, cultural norms, lack of trust, and corruption. In this context adaptation strategies should aim to meet the larger goals of reducing poverty, diversifying livelihoods, protecting common property resources and ecosystem services, and strengthening of collective action.[20] The following are examples of adaptation options that increase the resilience of people and ecosystems by improving access to water and ecosystem services in order to establish and maintain sustainable environments and livelihoods.

Increasing water supply and ecosystem services:

- Expansion of rainwater harvesting to improve rainfed cultivation and groundwater recharge

- Adoption of water transfer schemes
- Restoration of aquatic habitats and ecosystem services
- Increased storage capacity by building reservoirs

Decreasing water demand and increasing use efficiency:
- Removal of invasive non-native vegetation from riparian areas
- Improvement of water-use efficiency by water recycling
- Spread of drought-resistant crops
- Improved management of irrigated agriculture, e.g., changing the cropping calendar, crop mix, irrigation method and repair and maintenance of irrigation infrastructure
- Expanded use of economic incentives to encourage water conservation
- Improvement of urban water and sanitation infrastructure

Improving flood protection:
- Construction of flood protection infrastructure
- Enlargement of riparian areas
- Increased upstream storage
- Restoration and maintenance of wetlands
- Improved flood forecasting

Integrated Water Resources Management (IWRM) provides a useful framework for planning well coordinated and targeted adaptation measures to climate change. It is a systematic process to the sustainable development and equitable allocation of water resources through a holistic approach to water management. IWRM as a concept was first presented at the International Conference on Water and Environment in Dublin, and in Chapter 18 of Agenda 21,[3] a consensus document from the United Nations Conference on Environment and Development (UNCED) in Rio, both in 1992.

Successful IWRM strategies include, among others: capturing societal views, reshaping planning processes, coordinating land and water resources management, recognising water quantity and quality linkages, combined use of surface water and groundwater, protecting and restoring natural systems, addressing impediments to the flow of information, and including consideration of climate change. But there is also a risk in that IWRM, by being so ambitious, can encounter barriers both because it potentially challenges existing hierarchies and sectoral thinking, and because it may be too resource-intensive to apply in its entirety.

Vulnerability is a matter of circumstances

The ultimate objective of adapting water management to natural variability and climate change is to decrease the vulnerability of ecosystems and societies. But the concept of vulnerability may be interpreted in different ways that dictate the appropriate types of adaptation strategies.

Climate variability and change occur in the context of political, institutional, economic and social structures. These structures influence the way in which people and ecosystems are exposed, as well as to what degree they are vulnerable. People can be vulnerable to climate change because of lack of access to basic social services, exclusion from decision-making, or living in environmentally degraded areas where access to natural resources is restricted. The sum of all of these circumstances then dictates to what degree people are and will be influenced by climate and what capacity, freedom and opportunities they have to manage and adapt to climate related problems.[34]

As societies and communities undergo changes to bring them out of poverty, it is important to recognise that not all measures done in the name of development, e.g. increasing economic growth or introducing technological change, reduce vulnerability. For example, converting mangroves to shrimp farms may improve the economies of coastal farmers but leave them more vulnerable to coastal hazards.[1] Short-term economic gains can also be bought at the expense of long-term sustainability.

Vulnerability assessments are not static. They need to become continuous, normal processes that follow changes in societies, ecosystems and climate.[23] To create opportunity for successful adaptation strategies and promote resilience in both ecosystems and societies, it is important to understand the context of poor peoples' lives to grasp why they are vulnerable. Efforts need to be made to limit their exposure to the direct risks of climate change, floods or water shortage. But only through understanding what really makes people vulnerable can governments facilitate and broaden opportunities for engaging in resilient livelihood strategies. Likewise, only through understanding of people's strategies to adapt to current variability, and the limitations of and barriers to these strategies, can governments support people's adaptation.

Box 2: Principles of Integrated Water Resources Management (IWRM)

IWRM is based on four principles:
1. Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.
2. Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.
3. Women play a central part in the provision, management and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognised as an economic good.

Box 3: The vulnerability of the urban poor

Since 2007, the urban population of the world has been larger than the rural population, and by 2030 demographers estimate that two-thirds of humanity will live in large towns or cities. While drought is the primary concern in many rural areas, extreme rain events and cyclonic storms (more often and more intense) are acute hazards in urban environments, especially for the poor who live in the most hazardous areas. Flooding in urban areas is not only caused by heavy rainfall but as a result of this in conjunction with poor and inadequately managed drainage.[13] The water that does not quickly drain away causes problems, destroying makeshift houses and spreading diseases from unhealthy sanitation and waste management practices. The water that does quickly drain away, due to impervious areas such as roads, roofs and pavements, fails to recharge groundwater but instead moves quickly to downstream areas. In the long-term, this stresses groundwater levels in areas where adequate household water is an ever-pressing problem.

Many mega-cities such as Mexico City, Bangkok, Jakarta and Delhi are facing increasing water shortages. Drinking water is being transported from over 300 km away to meet demands in Delhi, and with increasing precipitation variability, unsustainable mining of groundwater and a severely polluted river system, the Delhi mega-urban region could face the same destiny as two historic capitals of the same region: Mohammed-bin-Tuglak's (1325–1351) Tuglakabad, near Delhi, and Akbar's (1556–1605) Fatehpur Sikri, near Agra, which were abandoned due to water scarcity.[29]

Population increase and erratic rainfall are important reasons for water shortage in cities, but also increased water harvesting and agricultural intensification in reservoir catchments. For example, competition between rural and urban demands for scarce water resources sometimes exacerbates the water shortage. Chennai in Tamil Nadu, India, is one such example.[10]

The stream of people moving to large urban centres with hope of better fortune increases each year and this trend has led to large numbers of people, especially the poor, settling and living in floodplains in and around urban areas.[13] Many of these areas lie outside of the formal city limits (peri-urban areas) so they are unplanned and unregulated. They are ignored in urban planning systems so they continually lack adequate drainage systems, water supply and sanitation facilities. They are ticking time-bombs waiting for excessive storms to hit.

Fatehpur Sikri, near Agra in Uttar Pradesh, India, was constructed by the Mughal emperor Akbar and served as the empire's capital from 1571 until 1585, when it was abandoned due to water scarcity.

Adaptation Strategies in Practice

The effects of climate change will greatly affect the economies and livelihoods for many of the world's citizens. River basins, floodplains and coasts are the geographical base where water is managed and they are the 'natural infrastructure' for adaptation.[18] People need to be encouraged, allowed and supported to sustain and improve their local ecosystems in ways that support their livelihoods and adaptive capacities such as protecting natural wetlands for hydrological services and provision of food and fodder.[24] Reducing vulnerability through promoting good and adequate health, finances, food security, water resources and ecosystems is the key to enabling people to adapt to stressors as they arise, including climate change.

In this section, a number of case studies are presented where different initiatives have been taken to reduce the vulnerability of the poorest groups by building sustainable livelihoods for current populations while at the same time promoting water conservation and ecosystem resilience. These include 'no regret' strategies that are, or have the potential to be, widely applied at a local scale where vulnerability is the greatest, i.e., in low-income regions prone to droughts and floods, such as large regions in Africa, Asia and Latin America.

Photo: Julie Wilk

Case Study 1:

Adaptation and water management in a South African river basin

In the Thukela river basin, South Africa, several regionally downscaled climate scenarios using different global climate models and emission scenarios have projected hotter winters and more extreme hydrological events, including longer, wetter and drier periods, for the period 2006-2050 as compared to 1961-2005.

A project involving researchers, government authorities, NGOs and small-scale subsidence and large-scale commercial farmers has engaged in a model-assisted process to assess the local impacts of climate change on water resources and produce policy options to local governments based on realistic assessment of future climate-related problems and relevant adaptation strategies. Between the workshops, based on requests from participants, the researchers compiled locally relevant climate change related information. The rationale behind the model-assisted participatory process was that: (i)

Photo: Julie Wilk

adaptation strategies should be ratified by those affected; (ii) knowledge and information should be transformed in several directions (stakeholders, planners, researchers); (iii) the process will improve understanding between groups.

The process has revealed that the adaptation strategies identified as promising measures for addressing future climate challenges are the same ones used to cope with current climate variability. These need to be strengthened and expanded but the same obstacles still exist. The greatest obstacle to implementing successful adaptation strategies is not the lack of know-how about the climate or how to cope or adapt to its effects. Obstacles include the small-scale farmers' lack of access to financing for equipment to prepare contours as erosion control, bunds to protect their houses from flooding, and materials for the construction of small reservoirs for sustainable household and agricultural water availability. Commercial farmers have difficulties getting permits to build new irrigation facilities, including reservoirs, because of a slow, complicated and incompetent bureaucracy. They also lack the certainty that they will be able to stay on their farms, which makes them more reluctant to make investments with long-term returns.

It is apparent that among farmers there are vast differences in levels of vulnerability to present risks and potential ones from climate change. Poor small-scale farmers are barely coping even in the current climate, while commercial farmers have a variety of buffers to fall back on. In a poor crop year, poor farmers live on another family member's meagre pension or sick benefit, borrow or beg food from their neighbours or relatives and stop buying 'luxury' food items such as vegetables, sugar and oil. Commercial farmers borrow money from the bank to tide them over or live on their savings and refrain from items like holidays and new vehicles.

Small-scale farmers lack sufficient government extension support to bring them the latest knowledge about agricultural technologies and methods, access to financing and sustainable markets, alternative activities allowing livelihood diversification and even positive role-models of farmers that have made changes allowing them to move from subsistence to commercial agriculture. Commercial farmers need trust, belief and a more fruitful dialogue with government officials and policies that give them confidence in the future, as well as more transparent and faster routines for gaining government permits.

This example illustrates that different pre-conditions and realities exist between groups depending on their level of vulnerability. Programmes and policies related to adaptation to climate change must reflect this and meet the needs and conditions of each group, with focus – of course – on the poorest. Participatory processes are important to engage stakeholders and produce more relevant and locally validated results that can serve as more solid ground in which to assess current adaptation strategies and their potential to meet future challenges.

Photo: Julie Wilk

Case Study 2:

Improving water management in rural India

Effective water management entails using the available water in any area in an effective and equitable way. SRIJAN (Self-Reliant Initiatives through Joint Action) is a small/medium size NGO that has been working since 1997 at the grassroot level directly with poor village women and men. They work to promote strong community managed institutions, partnerships, and enterprises to enhance poor peoples' access to natural resources and build their capacity to manage them in a sustainable manner. Their main focus is conserving and distributing water in order to improve livelihoods of the poor. Their initiatives involve about 18,000 families in 11 districts of three states in India. SRIJAN's professionals work in teams that live in district or sub-district headquarters and work directly with the rural poor.

One of their significant initiatives has been rehabilitating defunct, poorly functioning, high leakage water-storage tanks and irrigation canals. The physical work involves desiltation and lining the tank canals, bund strengthening, turfing on tank bunds, feeder canal treatment in catchment areas, sluice and weir repairs. Tank User Groups and Water User Associations were formed or supported to ensure lasting commitment to continued maintenance of the tanks and canals. These groups, comprised of farmers owning land in the irrigation command areas, especially those at the tail end, were encouraged to join a common platform to resolve the issues that plague tank/canal management systems. This also involved the support of local NGOs, State Government, district administration and donors. In one case the NGO's, with support from 11 strong Water Users Associations representing some 5,500 farmers, pressured the irrigation department for a transparent and more honest implementation.

Desiltation and lining of canals has increased the volume of water reaching the field in tail end areas and minimised water losses from leakage. This has meant reclamation of waterlogged land in some cases and increased irrigation water to the command area in almost all cases, resulting in increased agricultural productivity. In the command area of Samrat Ashok Sagar dam, 276 farmers got water for the first time, out of which 136 were marginal farmers. Contrary to expectations, 196 were at the tail end.

At every project stage active participation from all stakeholders is encouraged. Support is given to help farmers plan their cropping pattern based on the amount of water in the tanks each season, in obtaining credit from banks, and in getting technical information and information about inputs available from different government departments.

In some project areas, a benefit sharing programme was tested where the landless and small and marginalised farmers

not deriving any direct benefit from tank rehabilitation work were entitled to a small remuneration with which they could undertake an income generation activity of their choice. This amount was later repaid to the Tank Management Institution from profits. The farmers found that the initial allotted amount was too small for its purpose, so they each pooled all the money into a revolving fund, which they could borrow from in turns.

Challenges that have been identified and addressed are that the Water User Associations are not representative because they cover such large command areas. Thus, they are being decentralised to smaller groups to function more effectively. Big and influential farmers often take extra water for their fields by raising obstructions or breaking bunds so that tail end farmers routinely get less water. Women presently have no role in Water User Associations and this situation is slowly being rectified. Trust and openness are fostered through increased transparency and dialogue.

In other areas projects have been initiated, aimed to enhance people's income by giving better returns by introducing local initiatives that are linked with markets, while at the same time promoting efficient water use. Drip-based horticulture has been established in some areas and has increased incomes and provided more stable livelihoods by diversifying household activities.

Photo: Hanna Wolf, Swedish Society for Nature Conservation

Case Study 3:

Rainwater harvesting in India and elsewhere

Smallholder and subsistence farmers in arid and semi-arid regions, who have often not started to climb "the ladder of development",[30] depend largely upon themselves for managing their local water resources: rainfall, seasonal and ephemeral streams, and groundwater.

The most common approach to improve local water supply is to harvest rainwater, either by practices that aim at enhancing soil infiltration at the site, improving rainfed cultivation (in situ rainwater harvesting), or collecting and diverting rainwater to reservoirs. Rainwater harvesting structures have been documented in several ancient civilizations. Timing of their construction with changes in climate supports the hypothesis that people respond with rainwater harvesting and staying in their homelands, rather than with migration.[28] A cost-benefit analysis of on-farm rainwater storage systems for supplemental irrigation in Kenya showed that they are feasible solutions to crop failure in semi-arid areas.[27]

Modern rainwater harvesting projects are usually based on traditional practices, which are known from several regions, e.g., Africa,[39] South America,[7] and India.[28] Since the 1980s, construction of new rainwater harvesting structures has been particularly rapid in Rajasthan, a drought-prone state in northwestern India, where the traditional practice of building *johads* has been promoted and supported by the NGO Tarun Bharat Sangh (TBS).

Johads are curved embankments that collect the run-off from tiny streams in a micro-catchment, and until 2003 about 3,200 had been built, mainly in the Alwar district, with the help of funding from various sources. The work has shown that rejuvenation of traditional water harvesting structures on a large-scale is indeed possible. The work done by TBS has generated several positive outcomes,[22] e.g.:

- Release of social capital: Some village institutions have moved towards protecting forests, building schools and other developmental works.
- Increased water availability: In agriculture-dominated villages, increased surface and groundwater availability has improved economic gains, for example where farmers have been able to diversify into cash crops due to improved water availability. In villages where a significant proportion of village lands have been treated, most households have protected themselves against ill-

effects of drought for 3 to 4 years. In animal husbandry dominated villages, increased water availability has led to change in livestock composition towards more milk cattle and therefore a greater income.

- Other positive trade-offs: The process of building *johads* has resurrected village institutions in many villages. *Johad* building has led to protection of forests in catchments. Drudgery of women in fetching water, fuel wood and fodder has been reduced and their quality of life has improved. The quality of structures built by TBS has forced governments to raise the quality of their work. In some villages, people have started building *johads* on their own. Many of the large number of visitors from other states have been inspired to take up water harvesting in their areas.

In general, rainwater harvesting is considered to have mostly positive effects. Biomass production is enhanced, or at least crop failure due to dry spells is reduced, and soil erosion is reduced, since the rainwater harvesting structures trap sediments.[39] Also groundwater recharge is assumed to improve, but few field measurements are available. Nevertheless, reliance on rainwater harvesting, rather than on groundwater, may halt the salinisation of groundwater in coastal areas. In the West Bengal and Bangladesh, rainwater harvesting can serve as an alternative to using the water from the alluvial Ganges aquifers, which are polluted with naturally occurring arsenic.[28]

In Africa, rainwater harvesting has also been shown to have a positive effect on incomes,[39] but rates of adoption are still low.[9, 32, 40] One reason is that farmers often have no security of land ownership, and another is that they have limited access to local markets where they could sell surpluses of food crops or cash crops.[14]

There are also potentially negative trade-offs that have to be taken into account when considering rainwater harvesting. Land use patterns may change, e.g., when rainwater harvesting makes it possible to convert natural vegetation or rangeland into cropland. This may cause conflicts between pastoralists and sedentary farmers. Since rainwater harvesting results in decreased run-off to downstream locations, competition for water may also arise between upstream and downstream communities. To avoid, and solve, possible conflicts it is important to build water management organisations at successively larger catchment levels.

It is often assumed that water losses are smaller when water is collected in many small reservoirs upstream, rather than in one big reservoir at the end of the catchment.[2] However, there is little scientific support for this assumption.[10] Monitoring and modelling of the hydrological consequences of rainwater harvesting in different types of catchments is thus needed to provide decision support for further use and development of this technology.

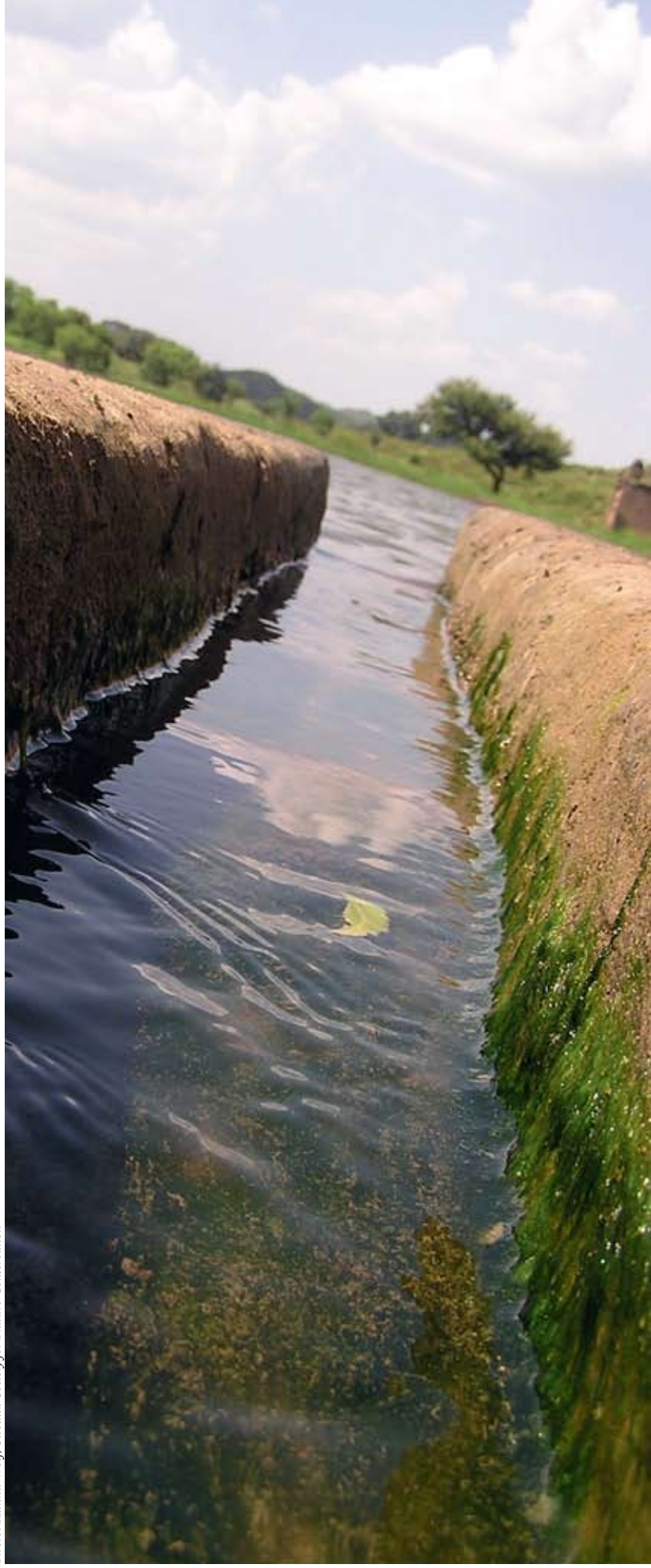

Photo: Hanna Wolf, Swedish Society for Nature Conservation

Case Study 4:

Agroforestry around Lake Victoria, East Africa

Agroforestry is a sustainable agricultural technique that increases the resilience of ecosystems by supporting biodiversity, decreasing soil erosion, improving water absorption, and enhancing soil fertility.[38] It also increases and diversifies agricultural production, thereby relieving the pressure to encroach forests and helping to save natural areas and preserve biodiversity. Production of fuel wood and housing materials also decreases natural forest degradation and provides families with cheaper and better quality fuel while preserving animal waste for fertiliser purposes. In addition to this, it sustains the capacity of the forest to store carbon in the trees and soil, thus aiding climate change mitigation.

Vi Agroforestry Programme is a Swedish NGO which has worked in the Lake Victoria region of Eastern Africa for over 25 years with a vision of "a sustainable environment offering good living conditions for farmer families". Focus has been on tree planting through agroforestry systems where small-scale farmers integrate appropriate trees and bushes with crops and/or animals, to improve the environment in various ways while simultaneously strengthening their livelihoods through increased and diversified production. Addressing environmental issues while maintaining and increasing productivity will be one of the key issues in regional agriculture over the coming decades.[17]

Vi Agroforestry works in seven project areas in Kenya, Tanzania, Uganda and Rwanda. The programme reaches over 1,200,000 people and to more than 5,000 civil society organisations through a strong extension service system. Since the start, the programme has contributed to the planting of over 100 million trees.

Results indicate that more households in the programme areas are producing a diversity of fruits and vegetables as compared to the control areas. A larger percentage of the programme households have established agroforestry systems like hedgerows, multipurpose trees, woodlots and trees on soil conservation structures. This increase in tree cover has significantly mitigated land degradation and sustained river basin management. The diversified and increased production has improved nutrition and thus reduced extreme poverty and hunger within the Lake Victoria basin. Land management practices promoted in the programme have increased soil fertility, land productivity and improved living conditions for smallholder households, and thereby decreased their vulnerability to climate change. Another positive side-effect has been increased employment opportunities.

Challenges that face agroforestry implementation in the programme are establishment of a sustainable local tree seed collection, poor soils with low nutrient and water holding capacity, land pressure (due to population growth and migration), and land ownership.

Photo: AnnMari Naeve

Photo: Frida Lanshammar

Barriers to Adaptation

The threat of climate change has greatly increased global awareness about the vulnerability of ecosystems and of large groups of people. Development programmes and strategies that encourage and enable stable livelihoods, that adequately ensure basic living standards and the ecosystems that support them, must top the priorities of national governments and international organisations. Many such strategies that aim to help people adapt to today's climate are the same ones that must be promoted and more concretely implemented to meet the climate of tomorrow. Though capacity building and more education on the causes and effects of climate change are needed in many parts of the world at all scales, even when people know what to do, other problems and circumstances hinder adaptation strategies from becoming reality. A long list of barriers exist, and the poorer the person the longer the list. The barriers include: lack of access to financial possibilities and markets, lack of cultural acceptance of change, gender bias, lack of acknowledgement and use of traditional knowledge, lack of cooperation between sectoral authorities and integration in policy plans, top-down or outsider interventions without local anchoring, weak institutions, lack of good governance, lack of trust, corruption, and lack of political linkage between the climate change processes and the water community.

Impaired water vision

The close integration between water resources and climate change issues has been poorly reflected at the international political level. In the negotiations of the United Nations Framework Convention on Climate Change (UNFCCC) there is little focus on water, and there is little mention of it in the reports from the UN Climate Change Conferences in Bali, 2007 (COP 13),[36] and Poznan, 2008 (COP 14).[35]

Separated strategies and lack of agreements

The challenge of climate change is too complex an issue to be dealt with by any one ministry.[12] This means that all relevant national sectors must be involved in climate actions and that efforts must be linked. Many countries already have national strategies for development and poverty reduction. The least developed countries (LDCs) are also in the process of preparing National Adaptation Programmes for Action (NAPAs – an initiative agreed under the UNFCCC). For the NAPAs to be seriously adhered to, and for concrete and successful adaptation to take place, their content must be linked to existing development and economic plans in each respective country. But a lack of

clear links between the content in the NAPAs, on one hand, and Poverty Reduction Strategy Papers, National Development Strategies, IWRM plans, etc., on the other, has been pointed out as a main weakness in these plans to date.[8]

About 40 percent of the world's people live in international river basins. Therefore, transboundary water management arrangements and legal agreements must be developed to provide an effective framework to share the water resources equitably. Around 60 percent of international watercourses are not governed by cooperative management agreements and 80 percent of the existing agreements are bilateral even though other partners may exist.[19]

Institutional barriers

Lack of recognition of institutional barriers and a discussion of how to overcome them hinders the creation and execution of successful adaptation strategies. In many countries financial resources are held at ministerial levels while local government actors who have more insight in needs and strategies on the ground lack the capacity, skills, and time to access these resources.[12]

The global attention that climate change receives puts much focus on the international scene where national governments negotiate mitigation strategies. In the adaptation discussions there are well-justified fears that many initiatives that arise at international level will become top-down efforts. There is a real risk that local stakeholders will lose any place of influence and action to determine their own strategies and future.[12]

Knowledge bias

There continues to be a great need to recognise knowledge held by local people. Although in the face of a changing climate it is not certain that present adaptation strategies will be sufficient in the future, yet they must be the starting point on which to begin. Local technologies that aid communities to cope and adapt to extreme weather events but do not advance

Photo: Mats Lannerstad

development of dryland technologies will keep these groups vulnerable.[34] Development thinking rarely includes traditional knowledge systems and if it does, it is very seldom that the two parts are integrated. To meet the challenges of climate change, adaptation strategies must encompass current local knowledge and practices because the new climate will, in some cases, be radically different from the present.

Lack of participation

One means to increase the inclusion of traditional knowledge in decision-making and strategic planning is through one of IWRMs grounding principles: participation. Without participation of local inhabitants to ensure commitment and engagement, all planned adaptation strategies will fail. True participatory processes across sectors and scales are meaningful when stakeholders at different levels of action can voice their opinions, share their knowledge and be involved in concrete decision-making. Top-down strategies rarely work well on the ground and may even lead to violations of basic human rights. Time-after-time it is discovered that the communities who share their best practice techniques and methods are those that can increase their resilience to change and challenges.[33]

Gender bias

In the developing world, women play a key role in natural resources management. They gather wood and water and they toil on the land. In addition, they are the mainstay of family togetherness and well-being; they prepare food and care for children, orphans, the elderly and the sick. As the globe heats up, and droughts as well as floods will hit more often, diseases will increase and women will be the ones who naturally tend to the sick, among their other duties. They will have farther to walk to find freshwater and collect fuel. If labour becomes limited, their responsibilities will suffer first. Because women are typically associated with 'home life', their knowledge of livelihood planning and of agriculture and the environment often goes unrecognised and untapped. They are told and forced to cope and adapt through decisions made by men. Though they are often livelihood managers, they are many times trapped by cultural and structural components which inhibit them from acquiring education and entrepreneurial skills keeping them out of more well-paying activities.[11]

Uncertainty

Few doubt that human-induced climate warming is real, but uncertainty still surrounds 'how much?', 'when?' and 'how fast?'. It can be difficult for decision-makers to understand what the rise of average annual or monthly temperatures really means for their nation or region. This becomes even more pronounced when it comes to projections of future water availability and flood risks, where different projections can vary significantly, and even be contradictory to one another. A gap in knowledge exists between knowledge about the climate cycle and the hydrological cycle, especially at temporal and spatial scales relevant to decision-making.[8]

Financing

The financial systems in place do not always reflect where the needs are. The organisations and agencies through which funds for climate change adaptation are channelled must be carefully chosen, and bear the responsibility of targeting the most vulnerable groups. This puts a strong pressure on local institutional capacity, knowledge and competence. At the same time, decentralisation in many areas has put a heavy burden on local government and it is often overwhelmed by massive responsibilities.[12] The success of local adaptation measures also relies on supportive institutions at higher levels.[5]

Photo: Julie Wilk

Overcoming the Barriers

Promoting Integrated Water Resources Management

Though the World Bank and the World Water Council predicted the increase of IWRM around the world already in the early 2000s,[7] its principles still need to be stressed and advocated if sustainable adaptation strategies to climate change are to be realised. In many countries water issues are divided among numerous government departments and are dealt with in a segregated manner. Strong sectoral linkages are prerequisites for meeting the enormous challenge of climate change and its vast array of effects in all facets of life, health, environment, transport, energy, and food security. Mechanisms must be put in place to cut across sectors and link programmes and strategies dealing with water and climate issues in concrete ways. IWRM can provide this framework, but priority must be given to its planning and implementation. This, in some countries, would require a radically new way of thinking, cutting across sectors to address water management in a holistic manner. Yet the climate change challenge requires just that: radical new thinking. Even acknowledging the principles of IWRM but only implementing parts of it would still be a significant leap forward for water management.

Improving National Adaptation Programmes for Action and making them transboundary

The NAPAs outline how each country will cope and adapt to climate change but these strategies can not work in isolation from the goals of development and economic stability. Better integration of good water resources and ecosystem management into climate and other national policies, especially national conservation, water, poverty and development plans, is essential. NAPAs have been criticised for being little different from development plans in general, for failing to involve major ministries and decision-makers in the countries in question, and for being project-oriented. But workshops organised by the World Development Report team in 2008 found that those involved in building the NAPAs were instrumental in creating awareness and that urgent adaptation projects have been identified,[4] while the Commission on Climate Change and Development see them as being more about capacity building than forwarding adaptation.[12] Nevertheless, NAPA is and should be considered as a process, and it is important to continue without losing momentum, by preparing specific projects for funding, and creating synergies with ongoing planning processes.[8]

It is particularly important that the river basin perspective becomes much more prominent in NAPAs, and that mechanisms are put in place to stimulate greater cooperation between transboundary countries on adaptation measures. This may be done under existing international frameworks such as the UN Watercourses Convention, which already encourages such cooperation.

Supporting the local level and participation

The local arena is where concrete adaptation will take place, and local organisations are best able to identify and reach the poorest groups and implement and encourage adaptation strategies that are locally ratified. Adaptation strategies will only work on the ground if they fit local conditions, including the physi-

cal landscape, cultural traditions and traditional knowledge. National governments might be unwilling to cede control, but adaptation efforts must be based on the opportunities and difficulties defined by local governments through their relationships to ministries.[12] It is therefore crucial to support local ownership of local strategies, since ownership is a precondition for sustainability,[12]. Ministries and public authorities should be encouraged towards greater attendance to the local level. It should be clearly recognised that adaptation should foster the realisation of fundamental human rights. Risk assessments with reference to these rights' standards can be useful tools for identifying and minimising any negative impacts at the local level.

Promoting and supporting the collection, assessment and dissemination of successful local adaptation strategies is essential to guard the wealth of local experience around the globe. Even if traditional practices, knowledge and adaptation measures prove to be insufficient in the face of the climate change challenge, they are the starting point on which to build to ensure local commitment, engagement, and willingness to adopt and integrate new approaches into locally-specific adaptation strategies.

Stakeholder participation must be the back-bone of all processes. In particular, women must be involved in decision-making at all levels in society and adaptation strategies and programmes must be gender-sensitive. If women should be part of the solution, they must be empowered and their knowledge must be recognised, utilised and integrated into adaptation strategies. Incentives should be linked to such strategies in order to increase the potential for their implementation and sustained application.

Managing uncertainty by adaptive planning

In spite of uncertainties in projections of future climate, on the spatial and temporal scales relevant for decisions, people working with water resources planning and management must be keenly aware that climate change will have consequences for their sector. Waiting for uncertainties to decrease is not a viable option. Rather, development of locally accepted adaptation strategies should focus on climate-related problems that exist already as part of today's climate variability. New information should be factored as it emerges and plans re-evaluated and adjusted accordingly. This is especially important when planning large, costly water management infrastructure such as hydropower and irrigation projects. If these are built on historical climate trends, increasing water shortage in some areas might in a near future lead to greater water stress for vulnerable groups and ecosystems.

Photo: Mats Lannerstad

Photo: Mats Lannerstad

Although learning to live with uncertainty is necessary, reliable tools for planning and management of climate adaptation under uncertainty still need to be identified. This includes ensuring access to regionally downscaled scenarios, as well as to impact assessments of regional relevance. Decisions should not be built on results from single scenarios, but on assessments of robustness of these scenarios, i.e., to what degree different scenario projections of climate change show similar results. Access to a set of regional projections (to ensure robustness), presented in a comprehensive way is a prerequisite for pro-active planning. Hydrological data needs to be shared among regions in accordance with the World Meteorological Organization (WMO) Resolution 25 on free and open exchange.

Finding fresh and flexible funding

People in local institutions and communities are the ones who can best identify and reach the poorest groups and implement and encourage adaptation strategies that are locally ratified. Decentralisation of many issues requires that local institutions are strengthened, supported and empowered. Climate change is a new challenge and it is imperative that additional funding must be allotted to development and support of adaptation strategies for vulnerable groups and ecosystems. These resources should be additional to official development assistance (ODA) commitments. According to the Bali Action Plan,[37] guiding the UNFCCC negotiations leading up to the UN Climate Change Conference in Copenhagen, 2009 (COP 15), resources to support developing countries' adaptation should be "new and additional", as well as "adequate, predictable and sustainable". Though some argue that climate change adaptation is about development, so that money can already be considered as targeted towards adaptation, others argue that climate adaptation finance is about compensation from rich and polluting countries to poor countries that have to adapt. The impacts of climate change will be huge and the need for funding to aid vulnerable groups and ecosystems to adapt to the changing climate is equally large. As a first step donor countries need to mobilise an additional USD 1-2 billion (in addition to ODA) to assist the vulnerable low income countries, and the second step is to use the funding mechanism created through climate negotiations.[12] In the long term, 'additionality' may only be fully implemented if financial resources are mobilised through means in addition to national budgets, and means which do not risk crowding out development assistance aimed at poverty eradication. In that perspective, "innovative means of funding", as called for in the Bali Action Plan, are greatly needed.

Donors need to find more flexible mechanisms to get funds to the level where strategies are being put into action. Microcredits should be more widely available and especially targeted to activities in line with adaptation strategies.

Channelling funds through government is advantageous because of good scale coverage. However, corruption can also eat away at these good initiatives. NGOs can only exist in a political context that allows them to exist and beneficially cooperate with government. Financing adaptation through both can increase the effectiveness of both. Strong NGOs are able to lobby local governments on behalf of the poor and hold governments accountable for service delivery. Linking NGOs to national planning also increases their accountability.[5]

As the risk of climate change penetrates different parts of society, the private sector will also become engaged. They are a key resource in adaptation. Corporate social responsibility is a means to engage local neighbourhoods in the areas of water resources, mobility and communication.[12]

Moving water to the forefront

Climate and water resources are closely interlinked. A changed climate will have far-reaching effects in all aspects of society. Addressing climate warming without giving water a central role is to fail to recognise its multi-dimensional role in ecosystem sustainability and livelihood security. It is most important that the central role of water in climate adaptation is moved to the forefront at future conferences, including the upcoming COP 15 in Copenhagen, 2009. Without recognising and addressing climate change impact on water, achievement of the Millennium Development Goals dealing with water access, health, food security, energy and sanitation will also be severely hampered.

In fact, climate adaptation is largely about adaptation of water management, and since improved water resources management is already urgent under present climate conditions, it is a win-win opportunity to move water to the forefront in climate negotiations.

Box 4: Recommendations – a short list

- The principles of Integrated Water Resources Management should be promoted and guide climate adaptation strategies.
- National Adaptation Programmes for Action need to be integrated with other national development plans and adopt a river basin perspective, including transboundary cooperation in cases of multi-national rivers.
- The local level is crucial in climate adaptation, and institutional reforms must be crafted accordingly. Mechanisms should be put in place to make sure that adaptation efforts respect, protect and promote fundamental human rights.
- Stakeholder participation must be the back-bone of all processes. In particular women must be involved in decision-making at all levels in society and adaptation strategies and programmes must be gender sensitive.
- Uncertainty about the future climate cannot be an excuse for action to be postponed. Adaptation strategies must both address existing climate-related problems and develop tools to plan and manage climate adaptation under increasing uncertainties.
- Fresh and flexible funding should be found to speed up investment in water management of vulnerable developing countries, in particular the least developed countries, to meet both the present Millennium Development Goals and the consequences of observed and projected climate change.
- It is imperative that additional funding must be allotted to development and support of adaptive strategies for vulnerable groups and ecosystems. These resources should be additional to official development assistance (ODA) commitments.

Photo: Neil Chatterjee

References

1. Adger, W.N., Huq, S., Brown, K., Conway, D. & Hulme, M. (2003). "Adaptation to climate change in the developing world", *Progress in Development Studies*, vol. 3, no. 3, pp. 179-195.
2. Agarwal, A. (2001). *Drought? Try capturing the rain*, Occasional Paper, Center for Science and Environment, New Delhi, India.
3. Agenda 21 (1992). *Protection of the Quality & Supply of Freshwater Resources: Application of Integrated Approaches to the Development, Management & Use of Water Resources* [Online], UN Department of Economic and Social Affairs, Division for Sustainable Development. Available from: http://www.un.org/esa/dsd/agenda21/res_agenda21_18.shtml (2009-07-02).
4. Agrawal, A. (2008). *The National Adaptation Programmes of Action* [Online]. Available from: http://blogs.worldbank.org/climatechange/national-adaptation-programmes-action (2009-07-02).
5. Ayers, J. (2009). "International funding to support urban adaptation to climate change", *Environment and Urbanization*, vol. 21, no. 1, pp. 225-240.
6. Barnett, T.P., Adam, J.C. & Lettenmaier, D.P. (2005). "Potential impacts of a warming climate on water availability in snow-dominated regions", *Nature*, vol. 438, no. 7066, pp. 303-309.
7. Bates, B.C., Kundzewicz, Z.W., Wu, S. & Palutikof, J.P. (eds) (2008). *Climate Change and Water*, Technical Paper VI of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.
8. Björklund, G., Tropp, H., Harlin, J., Morrison, A. & Hudson, A. (2009). *Water Adaptations in National Adaptation Programmes for Action: Freshwater in Climate Adaptation Planning and Climate Adaptation in Freshwater Planning*, Dialogue Paper to the World Water Development Report 3: Water in a Changing World, United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris. Available from: http://unesdoc.unesco.org/images/0018/001818/181887E.pdf.
9. Bodnar, F. & De Graaff, J. (2003). "Factors influencing adoption of soil and water conservation measures in southern Mali", *Land Degradation & Development*, vol. 14, no. 6, pp. 515-525.
10. Calder, I., Gosain, A., Rama Mohan Rao, M.S., Batchelor, C., Snehalatha, M. & Bishop, E. (2008). "Watershed development in India. 1. Biophysical and societal impacts", *Environment, Development and Sustainability*, vol. 10, no. 4, pp. 537-557.
11. Chitsike, C. (2000). "Culture as a Barrier to Rural Women's Entrepreneurship: Experience from Zimbabwe", *Gender and Development*, vol. 8, no. 1, pp. 71-77.
12. Commission on Climate Change and Development (2009). *Closing the Gaps: Disaster risk reduction and adaptation to climate change in developing countries*, Commission on Climate Change and Development, Ministry for Foreign Affairs, Stockholm, Sweden. Available from: http://www.ccdcommission.org/Filer/report/CCD_REPORT.pdf.
13. Douglas, I., Alam, K., Maghenda, M., McDonnell, Y., McLean, L. & Campbell, J. (2008). "Unjust waters: climate change, flooding and the urban poor in Africa", *Environment and Urbanization*, vol. 20, no. 1, pp. 187-205.
14. Drechsel, P., Olaleye, A., Adeoti, A., Thiombiano, L., Barry, B. & Vohland, K. (2005). *Adoption Driver and Constraints of Resource Conservation Technologies in sub-Saharan Africa*, International Water Management Institute (IWMI), West Africa Office, Accra, Ghana. Available from: http://www.iwmi.cgiar.org/africa/west/pdf/AdoptionConstraints-Overview.pdf.
15. Dyurgerov, M.B. & Meier, M.F. (2005). *Glaciers and the Changing Earth System: A 2004 Snapshot*, Occasional Paper No. 58, Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado. Available from: http://instaar.colorado.edu/other/download/OP58_dyurgerov_meier.pdf.
16. Eriksson, M., Xu, J., Shrestha, A.B., Vaidya, R.A., Nepal, S. & Sandström, K. (2009). *The Changing Himalayas: Impact of climate change on water resources and livelihoods in the greater Himalayas*, International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal. Available from: http://books.icimod.org/uploads/tmp/icimod-the_changing_himalayas.pdf.
17. International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) (2009). *Summary for Decision Makers of the Global Report*, Island Press, Washington, D.C. Available from: http://www.agassessment.org/docs/IAASTD_GLOBAL_SDM_JAN_2008.pdf.
18. International Union for Conservation of Nature (IUCN) (2009). *Environment as Infrastructure: Resilience to climate change impacts on water through*

Photo: Digital Archive Japan Inc.

investments in nature, IUCN, Gland, Switzerland. Available from: http://www.waterandclimate.org/UserFiles/File/PersPap%2002.%20Environment%20as%20Infrastructure.pdf.

19. Jägerskog, A. & Phillips, D. (2006). *Managing Trans-boundary Waters for Human Development*, Human Development Report Office Occasional Paper 2006/9, United Nations Development Programme (UNDP). Available from: http://www.unwater.org/downloads/jagerskog_anders.pdf.
20. Kelly, P.M. & Adger, W.N. (2000). "Theory and practice in assessing vulnerability to climate change and facilitating adaptation", *Climatic Change*, vol. 47, no. 4, pp. 325-352.
21. Kron, W. & Berz, G. (2007). "Flood disasters and climate change: Trends and options – A (re-)insurer's view" in *Global Change: Enough Water for All?*, eds. J.L. Lozán, H. Graßl, P. Hupfer, L. Menzel & C.D. Schönwiese, Wissenschaftliche Auswertungen und GEO-Verlag, Hamburg, pp. 268-273.
22. Kumar, P. & Kandpal, B.M. (2003). *Project on Reviving and Constructing Small Water Harvesting Systems in Rajasthan*, Sida Evaluation 03/40, Swedish International Development Cooperation Agency (Sida), Department for Asia, Stockholm, Sweden.
23. Matthews, J.H. & Le Quesne, T. (2009). *Adapting Water Management: A primer on coping with climate change*, WWF Water Security Series 3, WWF-UK, Surrey. Available from: http://assets.wwf.org.uk/downloads/water_management.pdf.
24. Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-Being: Wetlands and Water – Synthesis*, World Resources Institute, Washington, D.C. Available from: http://www.millenniumassessment.org/documents/document.358.aspx.pdf.
25. Mills, E. (2005). "Insurance in a climate of change", *Science (Washington)*, vol. 309, no. 5737, pp. 1040-1044.
26. Nater, T., Duchrow, A. & Sörensen, L. (eds) (2008). *Desertification: Coping with Today's Global Challenges in the Context of the Strategy of the United Nations Convention to Combat Desertification*, High-Level Policy Dialogue, Bonn, May 27, 2008, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn, Germany.
27. Ngigi, S.N., Savenije, H.H.G., Thome, J.N., Rockström, J. & de Vries, F.W.T.P. (2005). "Agro-hydrological evaluation of on-farm rainwater storage systems for supplemental irrigation in Laikipia district, Kenya", *Agricultural Water Management*, vol. 73, no. 1, pp. 21-41.
28. Pandey, D.N., Gupta, A.K. & Anderson, D.M. (2003). "Rainwater harvesting as an adaptation to climate change", *Current science*, vol. 85, no. 1, pp. 46-59.
29. Revi, A. (2008). "Climate change risk: an adaptation and mitigation agenda for Indian cities", *Environment and Urbanization*, vol. 20, no. 1, pp. 207-229.
30. Sachs, J.D. (2005). *The end of poverty: How we can make it happen in our lifetime*, Penguin Books, London.
31. Stern, N. (2007). *The Economics of Climate Change*: The Stern Review, Cambridge University Press, Cambridge.
32. Tabor, J.A. (1995). "Improving crop yields in the Sahel by means of water-harvesting", *Journal of Arid Environments*, vol. 30, no. 1, pp. 83-106.
33. Tompkins, E.L. & Adger, W.N. (2004). "Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change?", *Ecology and Society*, vol. 9, no. 2:10 [Online]. Available from: http://www.ecologyandsociety.org/vol9/iss2/art10.
34. Ulsrud, K. & Eriksen, S. (2007). "Vulnerability and adaptation to climate change: New challenges for poverty eradication" in *Climate Change Threatens the Fight Against Poverty*, Church of Sweden and Norwegian Church Aid, pp. 23-51.
35. United Nations Framework Convention on Climate Change (UNFCCC) (2009). *Report of the Conference of the Parties on its fourteenth session, held in Poznan from 1 to 12 December 2008 – Part One: Proceedings*, FCCC/CP/2008/7. Available from: http://unfccc.int/resource/docs/2008/cop14/eng/07.pdf.
36. United Nations Framework Convention on Climate Change (UNFCCC) (2008). *Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007 – Part One: Proceedings*, FCCC/CP/2007/6. Available from: http://unfccc.int/resource/docs/2007/cop13/eng/06.pdf.
37. United Nations Framework Convention on Climate Change (UNFCCC) (2008). *Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007 – Part Two: Action taken by the Conference of the Parties at its thirteenth session*, FCCC/CP/2007/6/Add.1. Available from: http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf.
38. Verchot, L. (2008). "A look over the horizon at climate change issues relative to forestry: opportunities for relevant forestry research toward 2030", *New Perspectives in Forestry Education. Peer reviewed papers presented at the First Global Workshop on Forestry Education, September 2007, Nairobi, Kenya*, eds. A.B. Temu, S.A.O. Chamshama, J. Kung'u, J.R.S. Kaboggoza, B. Chikamai & A.M. Kiwia, World Agroforestry Centre (ICRAF), Nairobi, Kenya, pp. 333-352.
39. Vohland, K. & Barry, B. (2009). "A review of in situ rainwater harvesting (RWH) practices modifying landscape functions in African drylands", *Agriculture, Ecosystems & Environment*, vol. 131, no. 3-4, pp. 119-127.
40. Woyessa, Y.E., Pretorius, E., van Heerden, P.S., Hensley, M. & van Rensburg, L.D. (2005). "Implications of rainwater harvesting in a river basin management: evidence from the Modder River basin, South Africa", *3rd Int. Conf. on River Basin Management, September 2005, Bologna, Italy*, eds. C.A. Brebbia & J.S. Antunes do Carmo, WIT Press, Southampton, UK, pp. 257-268.

Key Messages

- The principles of Integrated Water Resources Management should be promoted and guide climate adaptation strategies.
- National Adaptation Programmes for Action need to be integrated with other national development plans and adopt a river basin perspective, including transboundary cooperation in cases of multi-national rivers.
- The local level is crucial in climate adaptation, and institutional reforms must be crafted accordingly. Mechanisms should be put in place to make sure that adaptation efforts respect, protect and promote fundamental human rights.
- Stakeholder participation must be the back-bone of all processes. In particular women must be involved in decision-making at all levels in society and adaptation strategies and programmes must be gender sensitive.
- Uncertainty about the future climate cannot be an excuse for action to be postponed. Adaptation strategies must both address existing climate-related problems and develop tools to plan and manage climate adaptation under increasing uncertainties.
- Fresh and flexible funding should be found to speed up investment in water management of vulnerable developing countries, in particular the least developed countries, to meet both the present Millennium Development Goals and the consequences of observed and projected climate change.
- It is imperative that additional funding must be allotted to development and support of adaptive strategies for vulnerable groups and ecosystems. These resources should be additional to official development assistance (ODA) commitments.

Swedish Water House
www.swedishwaterhouse.se

Kooperation Utan Gränser
www.utangranser.se

Stockholm International Water Institute
www.siwi.org

Vi-skogen
www.viskogen.se

Church of Sweden
www.svenskakyrkan.se

SMHI – Swedish Meteorological and Hydrological Institute
www.smhi.se

Centre for Climate Science and Policy Research
www.cspr.se

Swedish Water House is administered by SIWI.

Stockholm International Water Institute, SIWI
Drottninggatan 33, se-111 51 Stockholm, Sweden
Phone +46 8 522 139 60 ✦ Fax +46 8 522 139 61 ✦ siwi@siwi.org ✦ www.siwi.org