Water Climate Toolbox

Deutsche Gesellschaft
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GIZ Water-Climate-Toolbox

Climate change is already affecting the quality and availability of water in developing countries in many different ways. Adaptation strategies are becoming necessary to react to droughts, floods, drinking water quality concerns and changes in seasonal patterns of rainfall. The impacts of future climate change will exacerbate pressures for increased use of water in growing communities, industries and agriculture.

Preparing and planning for the impacts of climate change on the water sector presents a unique challenge for developing countries and the work of GIZ.

The Water-Climate-Toolbox is aimed at water sector practitioners and offers tools and techniques to support adaptation action.

The Water-Climate-Toolbox was developed by GIZ in cooperation with 7 Consulting Companies:
AHT Group AG, CES Consulting Engineers Salzgitter GmbH, GFA Consulting Group GmbH, ICON Institute Consulting Gruppe, IP Consult (Part of the NIRAS Group), RODECO Consulting GmbH, Sachsen Wasser GmbH.

The Water-Climate-Toolbox contains the following fact sheets:

- Climate Change Adaptation
- Climate Monitoring and Prediction
- Dams and Reservoirs
- People-Centred Early Warning Systems
- Economic Incentives for Ecosystem Protection
- Flood Sensitive Planning
- Improved Stormwater Drainage
- Irrigation Technology and Methods
- Rainwater Harvesting
- River Basin Management
- Sustainable Groundwater Management
- Virtual Water
- Water Loss Reduction
- Water Pricing
- Water Reuse
- Water Stewardship
- Waterless Systems
- Artificial Recharge
- Desalination
- Ecological Restoration
- Preservation of Ecosystem Functions
- Vulnerability Assessment
- Climate Education

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Climate Change Adaptation in the Water Sector

Background

Climate change effects, such as global warming, changes in precipitation patterns and sea level rise, have severe effects on the hydrological cycle and may cause water scarcity, droughts, flooding and erosion (biophysical impacts). Climate change adaptation in the water sector is vital to increase resilience against these threats to economic growth, public health, infrastructure, social cohesion and political stability (socioeconomic impacts).

Many developing countries are located in the most affected regions, and the poor and thereof women and girls are the most vulnerable group.

> In Africa alone, 75 to 250 million people may face increased water stress by 2020 due to climate change.

The estimated annual costs of adaptation to a 2 degree warmer world vary between US$30–100 billion, of which 70 per cent is water-related. This requires that the full range of financing options are used, including innovative financing mechanisms, private sources and public funding from developed countries.

Adaptation Strategies

The impacts of climate change on the water sector can be categorised into water scarcity, increased uncertainty regarding future environmental conditions, and floods. The strategies to adapt to these impacts (Figure 1) are diverse and often interconnected. Each strategy includes a wide range of potential measures (Figure 2). In many cases, adaptation programmes comprise of no-regret or low-regret measures, which create benefits both with and without the impacts of climate change.

Diversification of Water Resources

In areas where water supply relies on a single source, the population is highly vulnerable to reduced rainfall. Diversification of water resources reduces the pressure on single sources and minimises the risks of water supply systems not providing water of adequate quantity and quality.

Added Value from Water Resources

With increasing water scarcity, it is crucial to use the available resources in a technically and economically efficient manner in order to maximise the resulting economic value per amount of water used. In the development context, it is also important to increase the socially sustainable value of water by aiming at equitable access and poverty reduction.

Stakeholder Dialogue and Conflict Management

Increasing water scarcity can cause or amplify national or transnational conflicts. Integrated Water Resources Management (IWRM) aims at the allocation of water resources in an equitable, transparent, ecologically sustainable and peaceful manner. Water management institutions can hereby connect stakeholders and promote policy development.

> The Mekong River Commission promotes cooperative and sustainable use of the Mekong resources by all lower riparian countries. It is a platform for expertise, training and standards development in transboundary water management.

Coordination and Sector-Policy Planning

As water is the primary medium through which climate change affects livelihoods and societies, water expertise must be included in the development of national adaptation strategies. Cross-sectoral planning instruments and a Nexus approach can improve the quality of water management and infrastructure, increase technical knowledge, and expand institutional and financial capacities to enhance water, energy and food security.

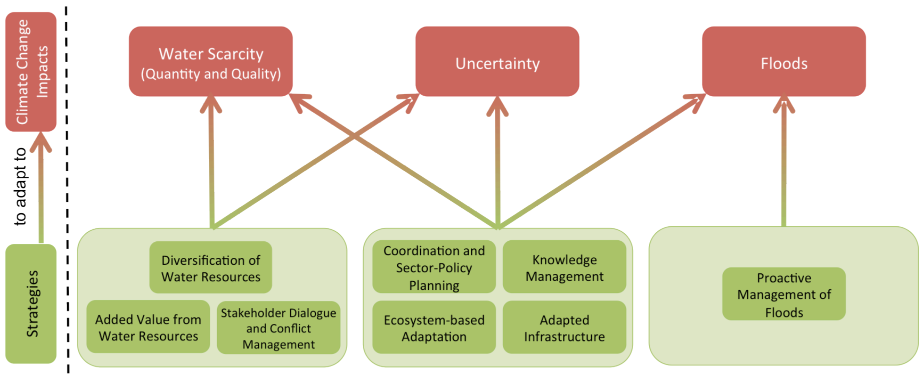

Figure 1: Climate change impacts and adaptation strategies

Knowledge Management

Knowledge management regarding the interface between climate change and the water sector is particularly central to reduce uncertainty. Regional climate change projections or impact and vulnerability assessments help to increase expertise of decision makers and practicioners as well as public awareness on the need for adaptation.

Ecosystem-based Adaptation

Humankind benefits from a multitude of ecosystem services. Increasing the adaptation capacity of humans and societies by preserving and making use of these services is called ecosystem-based adaptation. Floods and droughts, for instance, can be prevented by water storage in vegetation, soil and aquifers.

The main advantage of ecosystem-based adaptation is lower costs as compared to 'grey' infrastructure investments due to low demand in technical expertise and materials. Preserving biodiversity is a positive side effect.

> Water stewardship is an approach aiming to motivate water users, particularly the private sector, to reduce their environmental impact and support sustainable management of freshwater resources.

Adapted Infrastructure

Changes in amount and intensity of precipitation can lead to a breakdown of the service and regulation functions of existing infrastructure. As a certain amount of uncertainty always remains, project design needs to be resilient in dealing with changes that cannot be fully predicted. Multi-use infrastructure for water storage, flood retention, hydropower production and/or agriculture has positive effects on all water supply, energy and food security (Nexus approach) and is hence particularly adapted.

Proactive Management of Floods

Floods can have serious effects on human health and infrastructure. Early warning and disaster response systems, a close cooperation of stakeholders, as well as adapted flood protection infrastructure are needed to lower the impacts of water-related extreme events. Ecosystem-based adaptation can contribute to flood prevention on the watershed level.

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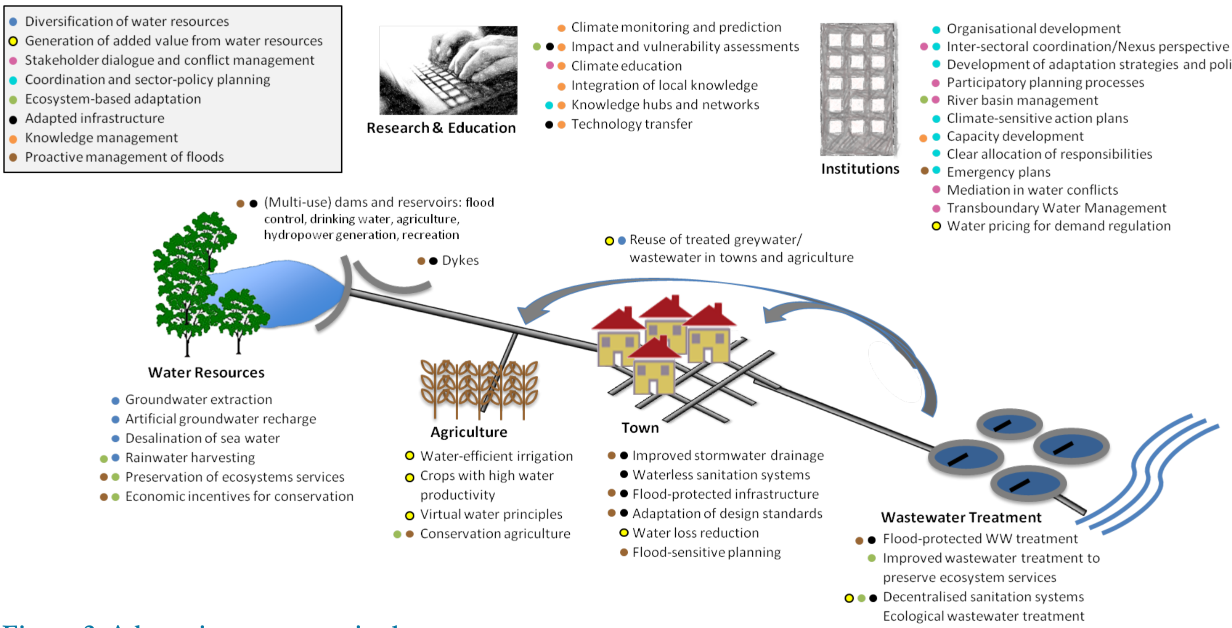

Figure 2: Adaptation measures in the water sector

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WATER
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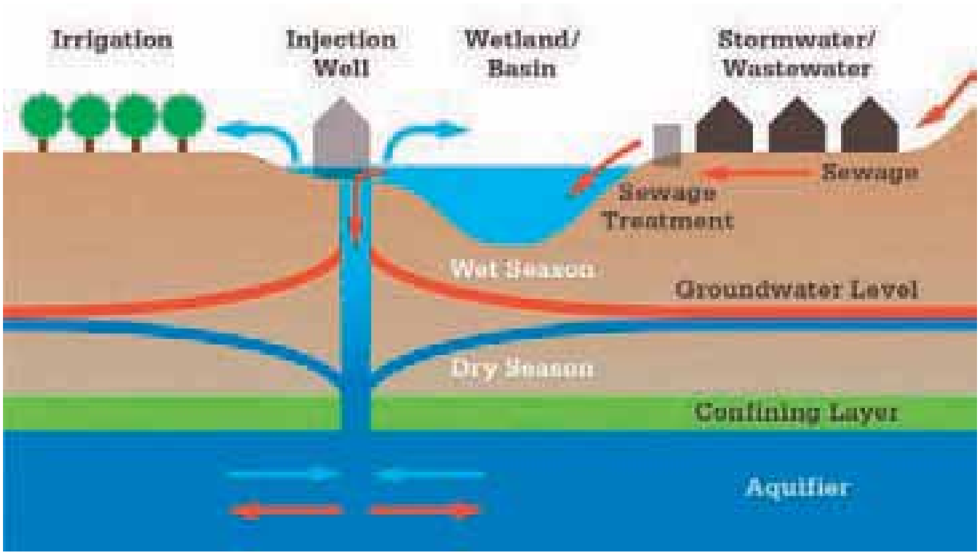
Artificial Recharge

... helps adapting to changing precipitation patterns by storing excess water for times of drought

Definition and Objective

The ongoing climate change is likely to further increase the frequency of extreme weather conditions around the globe. In many regions, excessive rainfall during shorter wet seasons is followed by longer dry seasons and periods of extreme droughts. The main objective of artificial recharge is to store excess water in underground aquifers during times of surplus that can be recovered during periods of water scarcity. Hence, artificial recharge can be compared to "water banking" and is often also referred to as "Aquifer Storage and Recovery (ASR)". Significant amounts of water can be stored in the subsurface through the implementation of large schemes, thus avoiding the need to construct large and expensive surface reservoirs and dams. However, simple rooftop rainwater harvesting and storage installation can also improve the water availability of households in many semiarid regions.

The augmentation of groundwater resources is accomplished through facilities and structures designed to enhance the natural replenishment or increase the infiltration of surface water into the aquifers. For shallow aquifers, this is often done with the help of infiltration ponds or surface runoff diversion structures. Deeper aquifers are usually recharged through injection wells.



Artificial recharge by the use of an injection well. In times of surplus, water is pumped into the ground (red lines), in times of water scarcity it can be recovered for use (blue lines).

Issues to Consider

Before implementation, detailed feasibility studies have to be conducted to ensure suitability of the aquifer and optimal design of the required surface installations. In addition, legal, economic, and environmental factors need to be considered for site selection and weighed against alternative options. This includes public acceptance and distance to the point of water use.

Advantages

- No large structures (dams) needed to store large volumes of water
- Stored water is relatively well protected from evaporation and pollutants
- Schemes can be implemented incrementally, keeping initial capital investment relatively low
- Depleted aquifers can be restored and saltwater intrusion can be controlled by applying artificial recharge
- Purification and improvement of water quality by infiltration and percolation of surface water through the soil
- Minimal land use for water storage required
- Cost-effective implementation and environmental friendliness in comparison with surface storage and dams

Challenges

- Detailed feasibility studies required before implementation of large schemes
- Continuous maintenance and qualified staff required in order to avoid clogging of injection wells and infiltration ponds, and prevent contamination of groundwater
- Regulatory constraints: compliance of artificial recharge with the country’s water and environmental legislation
- Recovery of stored water requires wells and pumping (energy demand)
- Undesirable chemical reactions can mobilize harmful substances

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Waterless Systems

… help adapting to climate change impacts (water scarcity) by saving freshwater

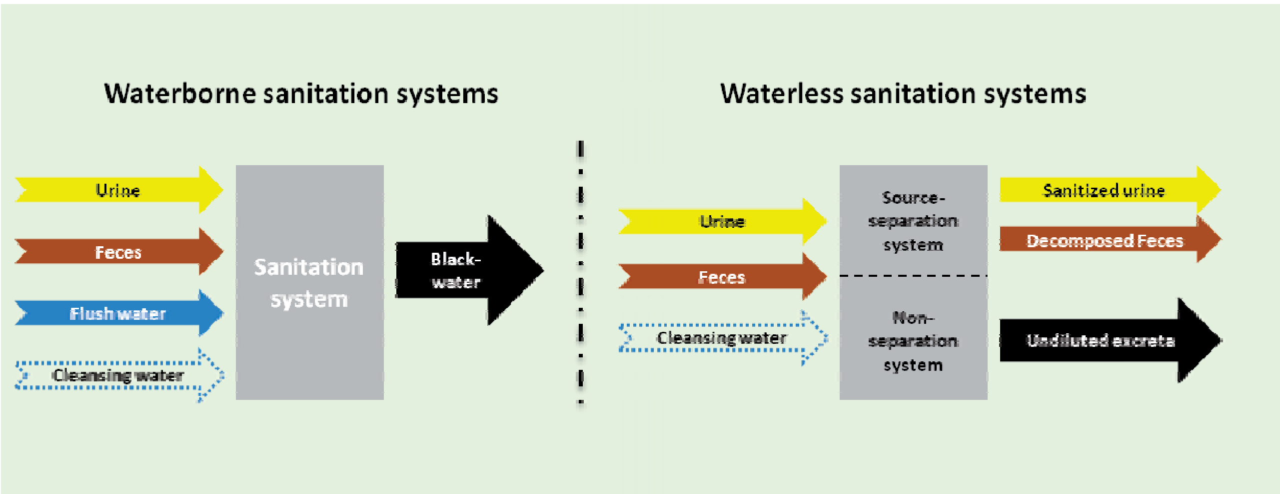
Definition and Objective

The ongoing climate change leads to an increasing stress on the world´s fresh water resources. Most sanitation systems put an additional burden on water resources as immense quantities of fresh water are used to transport human excreta from the point of generation to the treatment point and thereby get polluted by fecal matter. In contrast, waterless sanitation systems do not pollute water by using it as a carrier. As there is no alternative to water as a carrier, waterless systems collect, store and in some cases (partly) treat excreta on-site. Only small amounts of anal cleansing water, particularly common in Asian countries, might be used in such systems. Waterless systems can be distinguished in "dry systems" in which feces, urine and cleansing/flushing water are completely source separated, and mixed systems with no further separation of excreta and cleansing water.

A huge range of different technologies exist, ranging from traditional approaches to innovative technologies. Most waterless systems are able to fulfill the MDG criteria for improved sanitation systems defined by the Joint Monitoring Program (JMP) if they are adequately planned and managed.

The most common waterless sanitation systems include:

- Simple pit latrine (single or alternating pit)
- VIP latrine (single or alternating pit)
- Dry toilet (excreta are collected directly beneath the seat in a shallow pit, container, chamber)
- Composting toilet (also "Arborloo", "Fossa Alterna")
- Urine diversion dehydration toilet (UDDT)
- Waterless urinal
- Improvised systems such as defecation in a plastic bag ("flying toilet") or bucket latrine



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Issues to Consider

Waterless onsite systems need to be designed according to the users' needs and preferences. The type of anal cleansing material has to be considered when designing the user interface and storage capacity. Secure storage of excreta that protects both the environment and inhabitants is required. The cultural acceptability of reuse of urine and/or feces must be assessed before implementing ecological sanitation (ecosan) solutions. In addition, in areas with space limitations, the emptying of latrines and disposal of fresh or composted feces needs to be properly managed. In densely populated urban areas or slums where access for vacuum trucks might be limited or impossible, the handling of fresh (or partly decomposed) excreta puts manual pit emptiers under severe health risks and makes them prone to stigmatization. Health risks (especially through worm larvae and eggs) might also be caused by inappropriate management of composted feces from UDDT and composting toilets.

Advantages

Waterless systems…

- reduce consumption and pollution of water resources and consequently reduce energy consumption for water treatment (cost savings)
- reduce wastewater and sludge quantities and related disposal efforts and costs
- reduce contamination of grey- and rainwater due to separation from excreta
- reduce excreta-related soil and groundwater pollution due to reduced leachate
- are appropriate for arid and semi-arid areas
- are appropriate in areas where no sewer system exists and related cost savings for construction as well as for operation and maintenance
- offer additional benefits through reuse of feces (soil conditioner) and urine (fertilizer) in case of source separation
- are suitable for pro-poor approaches

Challenges

- Health and safety hazards for manual pit emptier need to be considered
- Non-availability of mechanized emptying services and non-feasibility of "fill and cover" in densely populated unplanned areas need to be addressed
- Adequate user awareness is needed to prevent health hazards due to unsafe handling of reused feces
- Particular care is needed in the selection of the facilities' locations and in training users in proper cleaning and maintenance measures to avoid potential nuisance of odor and flies due to lack of watertrap (siphon)
- Require proper management to avoid the generation of a source of diseases close to the household
- Gender sensitive project design needs to consider that the required user involvement of on-site systems might lead to increased household burden for women
- Limited social acceptance in cultures where flush-systems are regarded as advanced and waterless systems are perceived as less hygienic needs to be overcome

Simple pit latrine, Mount Kenya, Kenya
(Matthias Radek 2011)

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Water Stewardship

... integrates all relevant stakeholders into climate change adaptation efforts in the water sector

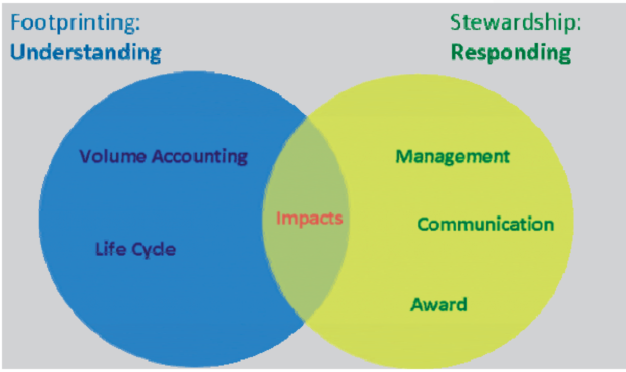
Definition and Objective

All over the world societies face mounting demand for clean drinking water to supply growing populations and increasing industrial demand, as well as to preserve healthy ecosystems. At the same time climate change impacts reduce the reliability of fresh water resources and put additional pressure on societies, particularly in water scarce regions. In this context the approach of Water Stewardship has been developed to effectively respond to the most pressing challenges. Water Stewardship is defined as the responsible use, management, planning and protection of water aiming to ensure the quality and availability of fresh water for current and future generations (European Water Partnership (EWP), 2012).

Water Stewardship provides an integrative platform for stakeholders from the business community, public sector and local communities for developing sustainable water management practices. It facilitates collective action through the definition of standards for voluntary compliance, complementary to the classical regulatory approach of environmental legislation.

Main aspects of the Water Stewardship concept are a structured approach towards sustainable water management, partnership between various actors from different sectors, transparent verification of progress in water management, and communication about best practices and achievements.

The concept of Water Stewardship is closely associated to Virtual water and water footprinting as methods for water accountancy. Virtual water estimations and water footprinting are powerful tools for measuring and monitoring direct and indirect water uses embedded into the entire supply chain of goods and services as well as for analysing related impacts of water use. For more information, see the climate Toolbox Factsheet "Virtual Water". Water Stewardship goes beyond pure water accountancy and impact assessment. It involves response mechanisms and creates positive incentives to change behaviours and practices.



Conceptual difference between Water Stewardship and water accountancy tools (www.ewp.eu)

Based on a detailed assessment of the water use through innovative water accountancy tolls, effective response strategies are developed. Water Stewardship has proven especially effective in the analysis and mitigation of risks related to water use, especially for water dependent businesses. Several Water Stewardship initiatives on local, regional and international level (e.g. World Economic Forum, European Water Stewardship, Alliance for Water Stewardship, CEO Water Mandate, Water Stewardship Forum) have been established, promoting standards of sustainable water management. Private and public institutions do not only become more efficient in water use but also become active advocates for better water management.

Issues to Consider

Water Stewardship should aim to involve all relevant stakeholders, especially large consumers in the private sector. Cooperation between the private and public sector needs to be strengthened and potentials and shared risks should be identified. Effective water management strategies for the private and public sector need to be based on detailed assessments of water use and associated impacts and risks, and require well targeted communication. In addition, innovative cross-sector cooperation needs to be put in place to provide solutions on community as well as river basin level. Water Stewardship raises awareness for the common interest for a sustainable availability of water resources among all stakeholders. In the long term sustainability of water resources can only be achieved by preserving and enhancing ecosystem services of watersheds.

Advantages

Water Stewardship…

- reduces social, economic and environmental impacts of water use
- encourages private action for effective water management on different levels through incentives
- supports communication of successful implementation and achievements in the private and public sector
- supports existing legal processes on country and supra-national level
- provides an integrated approach with standards and guidance for more effective collective action
- supports assessments and the mitigation of risks related to water use
- increases transparency in the water use practices

Challenges

- Requirement of trans-boundary agreements and actions need to be addressed to achieve water resource sustainability at river basin level
- Variety of initiatives on Water Stewardship may render communication difficult
- Parallel policy development is needed as initiatives of voluntary compliance do not substitute regulatory mechanisms in regions where environmental legislation is weak
- Experience with Water Stewardship is mostly limited to large international companies and needs to be transferred to smaller businesses
- Incentives are needed to promote the integration of sustainable water management strategies into operational plans of private businesses
- Adequate measures need to be created to avoid negative consequences of private sector-lobbying for small users

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WATER
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Water Reuse

... tackles climate change impacts (water scarcity) by using treated wastewater where possible

Definition and Objective

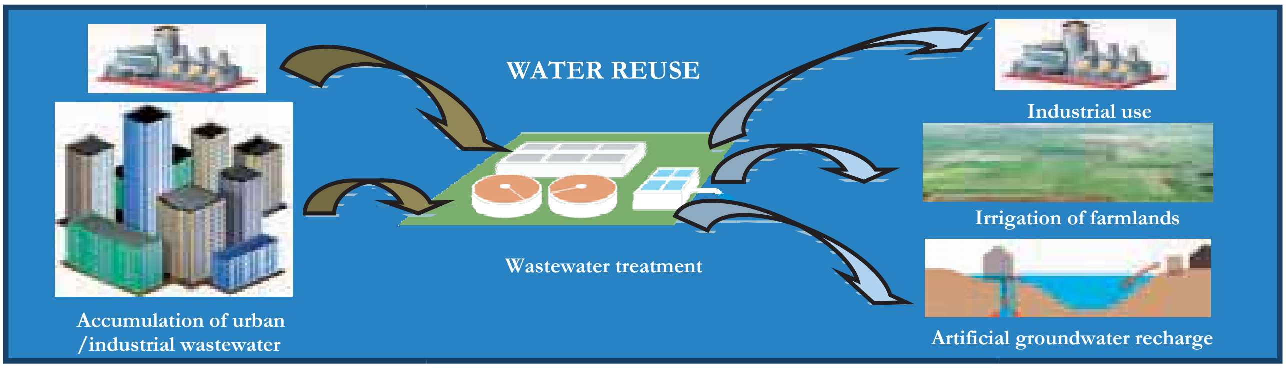
The global population keeps growing, along with a steadily rising water demand; but also increased per capita use of water, the demands of urban development, industry, agriculture and animal breeding put pressure on water resources. The ongoing climate change is likely to further increase the frequency of extreme weather conditions, resulting in longer dry seasons and periods of persistent droughts in some regions of the world. Hence, water resources are impacted early and heavily in many countries; developing countries are the most vulnerable. These climate change considerations make water conservation and sustainable use more and more important. An approach to this problem is the recycling of water and its subsequent use for a beneficial purpose. However before reuse, the wastewater requires certain treatment, depending on the degree of contamination and intended use.

Centralized approach

Since the agricultural sector accounts for 70-80% consumption of the world's fresh water, the reuse of wastewater proves most beneficial for irrigation purposes. Wastewater reuse has been successful for a wide array of crops, and can increase crop yields by 10-30%. It is in particular favorable in the arid and densely populated Middle East and Northern African region (MENA), where many urban Wastewater Treatment Plants (WWTPs) are being built; such as in Jordan, where already 66% of the countries' WWTP effluent is being used for irrigation.

Decentralized approach

On the other hand, also decentralized options are promising, especially the use of household greywater (wastewater generated from domestic activities, such as laundry, dishwashing, bathing). Since greywater has usually a low level of contaminants and can easily be treated, it is in particular suitable for irrigation of gardens and parks.



Generation of wastewater and options for reuse

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Issues to Consider

In general, the treatment of wastewater allocated for reuse requires removal of harmful substances, such as pathogens, helminthes or toxic chemicals. Other criteria are salinity, heavy metals, and harmful organic compounds. The World Health Organisation (WHO) published pertinent guidelines for the "safe use of wastewater, excreta and greywater for use in agriculture" (2006) to attain the goal of protection of public health. Food crops which are eaten uncooked must comply with highest standards, while non-food crops (e.g. cotton) and food crops being processed before consumption require less treatment. Furthermore, the choice of wastewater application method can impact the health status of farm workers and consumers. Here, low-cost drip irrigation systems have proven to be beneficial, as they provide increased health protections, higher crop yields and use less water. Reuse options have to be closely considered in the planning processes of WWTPs, in order to identify suitable WWTP locations and avoid unnecessary pumping. Education and transparency are essential to overcome public fears of use of wastewater in agriculture.

Advantages

- Reliable water source
- Substitution of uneconomic water sources, e.g. ground water pumping from great depths connected with high pumping costs
- Lower dependency on other water sources
- Reduced exploitation of sensitive ecosystems (surface and ground water sources) by substitution with treated wastewater
- Reduced nutrient loads in receiving waters
- Reduction of cost and energy intensive mineral fertilizers due to remaining nitrogen in the treated effluent
- Potential utilization of existing irrigation infrastructure for WWTP effluent discharge
- Reduction of required WWTP capacity at lower investment cost by reuse of greywater

Challenges

- High wastewater treatment demands need to be achieved
- Regulations need to be followed correctly to avoid water-borne diseases
- Health and environmental risks due to potential industrial discharge need to be mitigated
- Need for farmer education (health risks, crop restriction, and choice of wastewater application) has to be allowed for
- Consumer concerns need to be mitigated, i.e. by awareness-raising for safe food processing
- Legal framework needs to be found (prohibition/ severe restrictions, or lack of policy in many countries)
- Efficient monitoring needs to be established (reuse water quality, food inspection, public health)
- Environmental effects (salinization and heavy metals in the soil) need to be mitigated

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Water Pricing

... contributes to a more efficient water use as climate change causes decreasing water resources

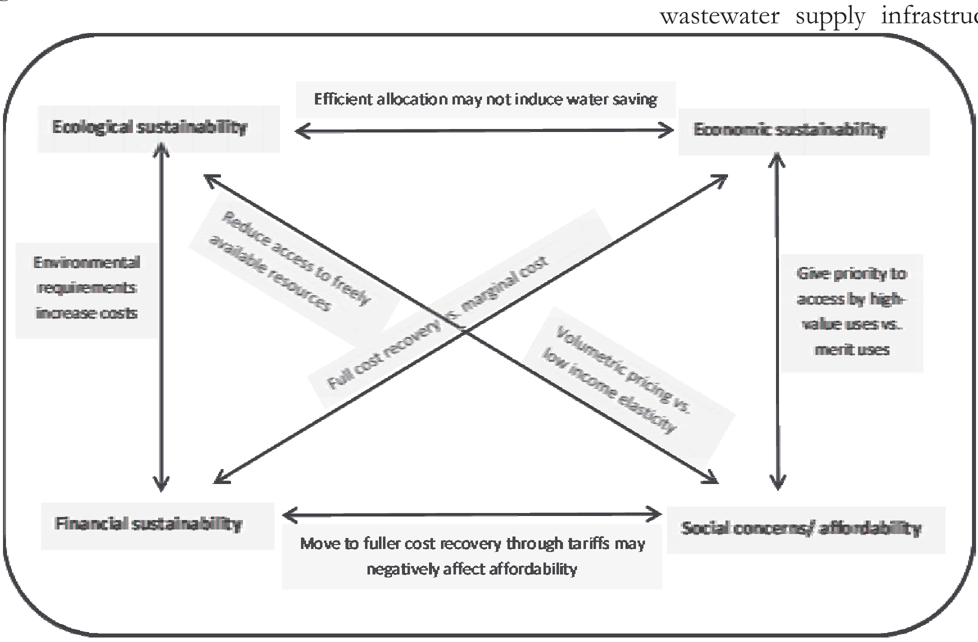
Definition and Objective

In the context of climate change and water scarcity adequate water pricing has increasingly been recognised and adopted as an acceptable policy and regulatory instrument. It aims at sound water resource management and provides incentives for water conservation and resources protection.

In numerous countries and regions water resources are prone to depletion and/or contamination. The implementation of different policy tools such as water user charges, pollution charges, tradable permits, fines, raw water tariffs, etc. has become a requirement from an environmental point of view, mainly applied so far in higher income countries. The four objectives of a water pricing policy, i.e. economic, ecological and financial sustainability and the consideration of social concerns as illustrated below are often subject to conflicts. Therefore policy-making becomes a trade-off between these 4 goals.

Pricing of water supply and sanitation services

Water and sanitation service provision implies cost comprising a variety of components. However, the elements of the so called full cost of water use and their estimation/calculation are still disputed, but are usually considered to comprise full cost of water supply, opportunity cost and economic/environmental externalities. The major difficulty in developing countries is to cover those cost elements which are beyond full cost of water supply and sanitation services. Any contribution to environmental services or appropriate sustainable water resource management is therefore difficult to enforce. Due to lack of affordability in some cases it is even impossible to charge the full supply costs. Hence, capital cost necessary to sustainment and infrastructure cannot always be captured through water tariffs. Water pricing/tariff setting is usually a compromise between elements of cost coverage, equity amongst users, economic efficiency of the water and wastewater supply infrastructure, availability of water, local affordability and willingness of the users to pay and other socio-economic factors.



Pricing Water Resources and Water and Sanitation Services (OECD 2010)

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Issues to Consider

In setting water tariffs as an important dimension of water pricing it is vital to consider the financial objectives of the water utility and the social implications of water supply (i.e. provision of life line quantity of affordable water). Economic objectives of water supply aiming at enhancing the economic potential of the supply area need to be reconciled with operational objectives of the utility to generate sufficient liquidity for continuous and sustainable high standard water supply and sanitation services. Further to be considered are water demand management objectives and investments in infrastructure, operation & maintenance (O&M) and replacement requirements for a hygienic and environmentally sound water supply and sewerage service. Before a tariff can be designed and applied, all the above elements need to be carefully examined.

Tariff structure	Description
Flat or uniform rates	Rate is charged for unmetered, unlimited volumes with a constant price per unit of time. Simple to design and administer, but no incentive for conservation of water.
Increasing/ decreasing block tariffs (volumetric)	Rates staggered into blocks of volumetric range. Price increases favour smaller, mainly poorer users and provide incentive to conservation. Price decreases favour larger consumers, mostly industries. No incentive for water conservation
Single volumetric rates	Rate is charged for metered consumption, i.e. a single rate per cubic meter is charged regardless of volume consumed. No incentive for water conservation.
Seasonal or peak rate	Rate adjusted to a specific period of the year or day. Can provide incentive to conserve water in critical seasons.
Conservation rate	Combination of structures to achieve greater efficiency and water conservation. Mostly done with progressive (increasing) block rates and peak rates.
Capacity rate	Based on the size of water-using appliances of the customer. Difficult to administer and little incentive for water conservation.

Advantages

- Cost coverage for water supply services
- Incentives for increased efficiency and accountability of service providers
- Incentives for water conservation and efficient water use by consumers
- Allows adequate maintenance and expansion of water supply and sanitation systems
- Adequate wastewater charges can help reducing pollution of water resources

Challenges

- Achieve trade-off between different objectives, e.g. cost coverage, equity amongst users, economic efficiency and affordability and willingness by consumers to pay.
- Avoid possible exclusion of the poor (affordability)
- Make sure that users in developing countries are able and willing to pay an adequate water tariff for water and wastewater services provision.

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Water Loss Reduction (WLR)

... enables suppliers to reduce shortages while climate change causes increasing demand

Definition and Objective

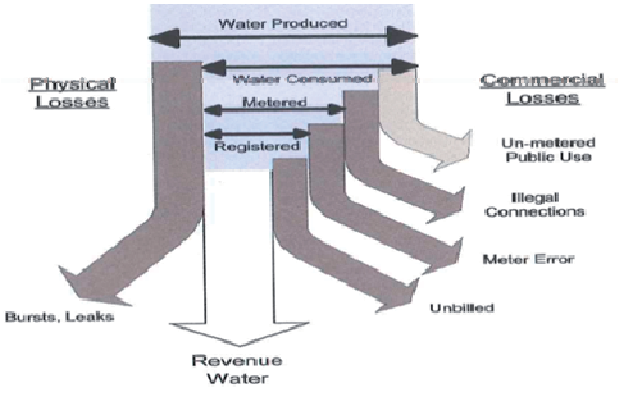
Increasing global water demand and the on-going climate change force societies to deal more sustainably with the resource "drinking water", e.g. by an optimized safeguarding of water resources.

Therefore, legislators, water utilities and consultants need to work towards a significant reduction of water losses and increasing revenues to maintain and upgrade the systems. The basis is the generally accepted water balance according to the International Water Association IWA which shows physical and commercial losses from the source to the consumer. The application of the water balance requires an accurate collection of real time consumption data. Defined performance indicators such as water losses per connection, infrastructure leakage index, pressure management index, annual saving potential, etc. should be calculated to choose the most effective and efficient solutions for the reduction of water losses, decrease of operation costs and increase of revenues.

Public awareness raising campaigns are means to support the utilities in detecting visible leakages, to be repaired by specialised contractors. The detection of invisible, unreported leakages and illegal connections is more challenging. Specialised contractors with modern equipment are able to detect leaks of mains and report those to the relevant technical, financial and/or legal department for follow-up.

The results received should be fed into the Network Information System (NIS) of the utilities to prepare hydraulic modelling and proofs, planning network extensions, rehabilitation work and to procure sustainable equipment like pumps with pressure surge tanks and stabilizers or high quality water meters as well as to conduct regular and preventive maintenance. The NIS also strives to generate an Asset Management System like the Check Up Program for Small Systems (CUPSS).

Pressure main bursts (USAID)



Overview of defined water loss components (UNW-DPC)

Issues to Consider

The reduction of water losses requires a holistic approach and a global understanding of water network systems, including common definitions, knowledge of water laws, NIS, special demands, pressure zones, current hydraulic calculations, essential assets and local billing systems. The first step in the water loss reduction process is to set priority criteria with major expected benefits according to the water balance, taking into account the water supply process from the source to the consumer. The next step is to ensure a proper recording of the water abstraction/production in order to ensure an optimal balance between abstraction and consumption.

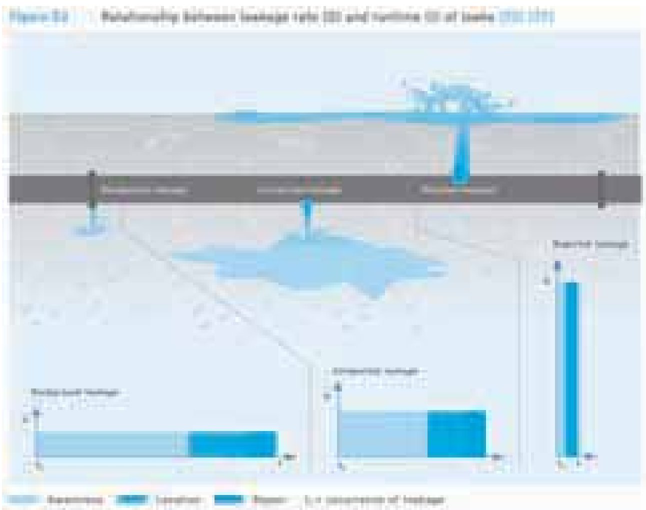
In addition, clear procedures in dealing with unauthorised water use, illegal connections, defective gauges or wrong measurements need to be defined providing a sound legal framework to the utility.

Advantages

- Water resources like wells and springs can be used more effectively and sustainably
- Water demand data can be crosschecked continuously allowing for optimized water demand forecasts
- NIS can be upgraded and used for other utility related functions and decisions
- Revenues can be increased by collecting fees from customers with unknown, wrong and/or unauthorized connections or illegal users
- Cost of energy and human resources can be decreased substantially

Challenges

- Make sure that water consumption does not exceed the renewal rate of the water resource
- Make sure that the utilities can act within a sound legal framework in particular to deal with unauthorized use, illegal connections and pollution
- Strive for balanced consumption patterns with a storage and pressure management working at minimum peaks
- Implement billing based on Life Cycle Cost for different customer categories
- Create synergies between water use reduction and water loss reduction



Relation between leakage rate and runtime of leaks

Pressure	Diameter hole	Leakage flow rate		
m	mm	l/ s	m³/h	m³/year
30 m	2	0,05	0,17	1497
	4	0,20	0,71	6205
50 m	2	0,06	0,23	2008
	4	0,26	0,92	8067

Leakage flow rate of holes at different pressure
(Bauhaus University Weimar)

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WATER
CLIMATE

Vulnerability assessment

... estimates the impacts of climate change and helps planning adaptation measures

Definition and Objective

Vulnerability describes a degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. System's vulnerability is determined by multiple factors and processes. The Intergovernmental Panel on Climate Change defined it to be a function of its exposure to the adverse effects of climate change, its sensitivity to these effects, and its capacity to adapt to resulting changes (IPCC 2001).

The purpose of assessing the underlying factors of vulnerability is to identify policies or measures that reduce vulnerability, increase adaptive capacity, or illuminate adaptation options and constraints (O'Brien et al. 2004). As a first step, mapping of vulnerability can be used to identify areas of high vulnerability to climate change and other stressors. Afterwards, case studies of the identified areas can provide a better understanding of the underlying causes and possible policies to effectively address vulnerability. These highlight the most vulnerable sectors or systems and the areas in which there is a need to act.

Various techniques can be used to identify strategic options, ranging from simple brainstorming to complex software solutions. On that basis, strategic adaptation measures will be developed to guide government in dealing with these vulnerabilities. They help the policy makers and managers to identify the areas of highest susceptibility and impact, in order to reduce vulnerability and enhance capacity building, by concentrating efforts in those locations.

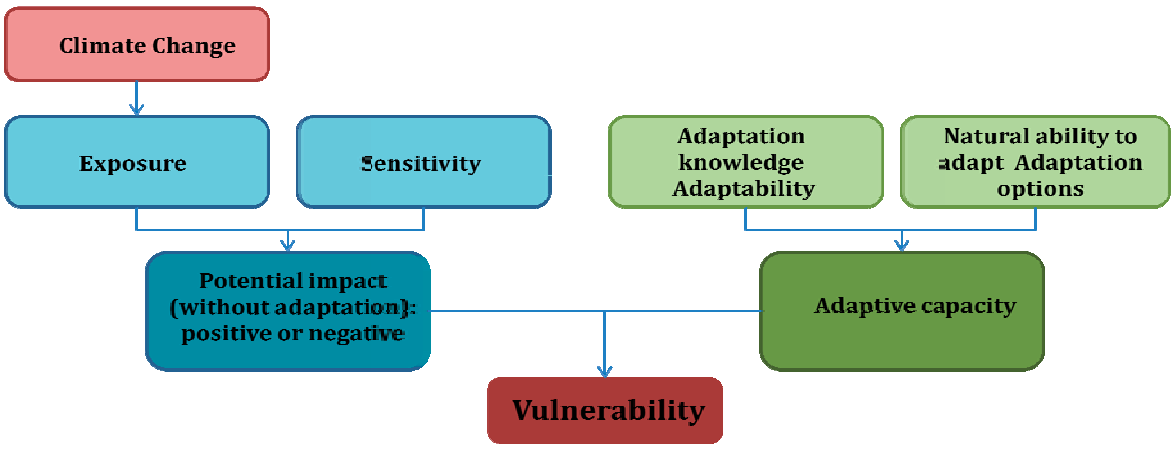


Fig. 1: Concept of an climate-related vulnerability assessment (changed according to: www.nordwest2050.de, Werkstattbericht 11, Juni 2011)

Issues to Consider

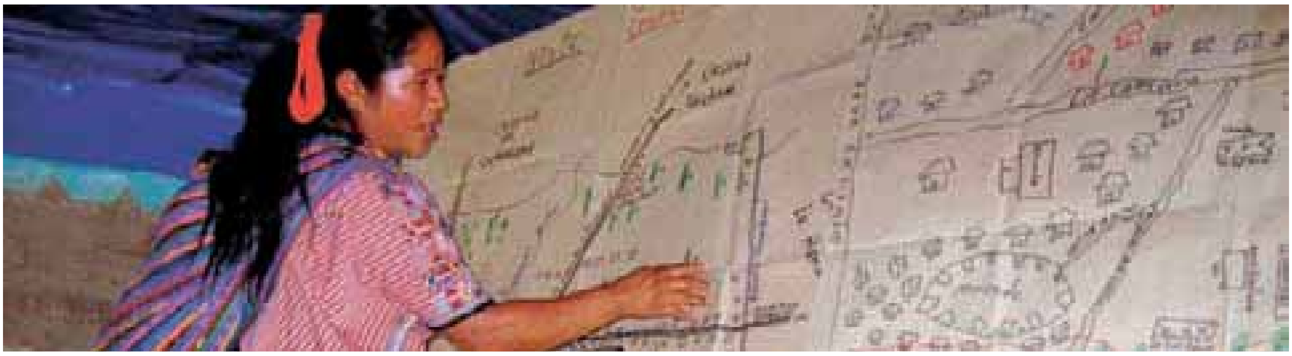
Vulnerability assessment is a critical component of en effective approach, which identifies vulnerable populations and ecosystems. It describes the complex state of vulnerability caused by the interactions between social, environmental, economic and political factors. It is advantageous to integrate the vulnerability assessment in the analytical step of project planning, e.g. during a base-line assessment, and to carry it out in a bottom–up-approach including all stakeholders especially the beneficiaries. The multi-disciplinary aspects of the vulnerability assessment require a lot of experts' knowledge and also community based support. It is a tool for participatory planning and decision-making concerning measures to mitigate climate change.

Advantages

- Provides a detailed overview of the current socio-economic and climatic situation
- Estimate of future scenarios
- Decision-making support for the weighting of opportunities and threats for strategic planning
- High degree of cooperation promotes the stakeholder dialogue
- Identification of important operational fields
- Awareness-raising of political decision-makers

Challenges

- Standardized methods for analysis and evaluation do not exist
- Requires a lot of experience and detailed studies in various fields relating to climate change and effects
- Complex processing of data
- Methodical and technical skills requires



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Virtual water

... illustrates inefficient water use and thereby helps adapting to climate change impacts (water scarcity)

Definition and Objective

As water shortages emerge around the world, due to climate change and the sheer demand for water, the export of water becomes a political topic.

Besides the water people use for drinking or washing, they consume by far more water through the production of goods or services they use. Water that is

- used for the production process of an agricultural or industrial product or
- contained in the product

is called virtual water. Virtual water is the amount of water that is embedded in food or other products needed for its production. It is the volume of freshwater used to produce the product, measured at the place where the product was actually produced.

The adjective 'virtual' refers to the fact that most of the water used to produce a product or service is not contained in the product. The real-water content of products is generally negligible. For instance, it takes 1,300 cubic meters of water on average to produce one metric tonne of wheat. The precise volume can be more or less depending on climatic conditions and agricultural practice. For more examples see the table from FAO.org, below. Virtual water is the water used in the entire process of producing a product or service. Two important factors determine this volume: climate conditions and agricultural practices. Therefore virtual water provides new impulses to the debate on the sustainable use of resources. Water is a scarce good and thus should be treated economically. There is an urgent need to develop appropriate concepts for combining water management practice and economic thinking. By raising awareness about water use efficiency and illustrating inefficient production processes, the concept of virtual water can contribute to a more efficient water use on different levels:

- To increase local water use efficiency by creating awareness, charging prices based on full marginal cost and by stimulating water saving technology.
- To improve water allocation efficiency. People allocate water to serve certain purposes, which generally implies that other purposes are not served. Choices on the allocation of water can be more or less 'efficient', depending on the (economic, social and ecological) value of water in its alternative uses.
- Enhance the global water use efficiency. Places in the world where water demand is high are quite often places where water availability is low. A water-scarce country can therefore aim at importing products that require a lot of water instead exporting products which require much water.

The integrated water fee is a tool that uses virtual water to give water consumption during production processes a price. It thereby contributes to the substitution of water-ineffective products by more effective products.

Virtual Water in consumption products (fao.org)

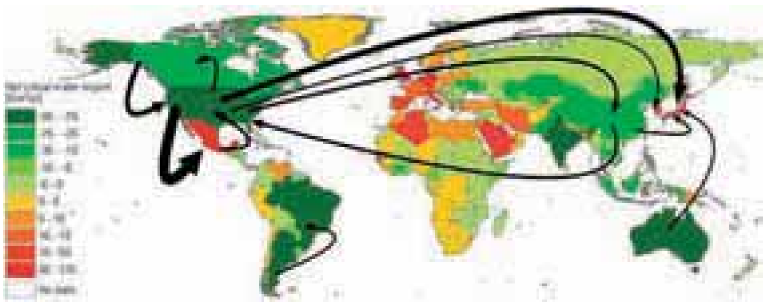
Issues to Consider

Virtual water is the water used in the entire process of producing a product. If you add the virtual water of all products and services used by a human, you obtain his/her individual “water-footprint”. The so-called "water footprint" is an indicator of the direct and indirect water consumption of a consumer. The "water footprint" of an individual, a community, a country or an enterprise is defined as the total volume of freshwater used by an individual or a community as a consumer, or a factory for the production of goods and services.

The water footprint of a country is determined by factors such as

- gross national income of a country,
- the type of goods consumed by a population,
- climate,
- efficiency of water use and
- management of water and water resources.

For more details see http://www.waterfootprint.org



The water footprint of humanity (Hoekstra/Mekonnen 2011)

Advantages

- Virtual water is a global issue that provides new impulses to the debate on the sustainable use of resources.
- The concept of virtual water raises people’s awareness that water-intensive and export-oriented agricultural use in arid regions of the earth is comparatively unprofitable both in an ecological and economical sense.
- It can be used for monitoring networks, including the detection of climate change impacts.

Challenges

- While virtual water clarifies the water consumption of products and services, environmental impacts, for example the unrecognized tradeoffs between energy or the production of greenhouse gases and water, are not considered.
- The practical application of virtual water trade is as well inhibited by subsidies and import restrictions.

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Sustainable Groundwater Management

... safeguards a freshwater resource under changing climatic conditions

Definition, Objective and Description

The importance of groundwater resources is likely to rise due to the immediate effect of climate change on the surface water systems. The future sustainable groundwater management (SGM) will thus have to balance the growing demand against the more restricted supply due to possibly lower aquifer recharge and increasing deterioration within the limits of the respective aquifer.

SGM is to be based on an aquifer-covering, frequent monitoring system, which provides a range of data on the characteristics of the aquifer, foremost on the current groundwater level, but also quantity and quality, etc. This data helps to develop an improved understanding of the aquifer and thus to determine the limits of water withdrawal in view of maintaining the aquifer's buffer and contingency capabilities.

When production rates exceed the natural recharge rates substantially, i.e. when resources are overexploited, the groundwater storage capacity of the aquifer can be severely damaged. Overexploitation may result in geotechnical, architectural and hygienic problems or provoke hydraulic shortcuts, which can lead to salination or other deteriorations of the groundwater. Groundwater thus often acts as or is turned into a finite resource and in many areas peak non-renewable water, i.e. a production decline following a peaking of the water withdrawal, can be observed. Consequently, the resource water is sometimes compared with oil; yet, in contrast to oil, there are needs which can be met by water only.

In addition to this direct anthropogenic impact on the groundwater resources, decision makers and planners working on Integrated Water Resources Management (IWRM) have to take into account the mainly indirect effect of climate change on groundwater. Groundwater is closely interlinked with the surface systems concerning water, land use, vegetation and soil properties. Thus, the increase in temperature which reduces the water content of rivers, lakes, plants and soils therefore entails not only lower groundwater recharge rates but also losses of the aquifers to the surrounding, dried out environment.

Reversely, poor groundwater management can also add to climate change impacts: a significant part of the total annual sea level rise is caused by large-scale groundwater exploitation as the extracted groundwater eventually winds up in the sea, states the Utrecht University (Doi: 10.1029/ 2010GL044571).

SGM can mitigate the damages done and impacts to come on groundwater resources, if it is addressed and put into effect as a decisive part of IWRM. A broad range of efficient short and long-term measures can help mitigate the effects of climate change. Examples include:

- Replacing groundwater – which is often of drinking water quality – by treated grey or rainwater
- Using in-situ rainwater harvesting for securing soil infiltration and recharging aquifers
- Improving irrigation performance by using closed systems or drip irrigation
- Identifying appropriate forms of land use
- Delineating (ground)water protection zones
- Promoting and integrating best practices into water policies

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BMZ Federal Ministry for Economic Cooperation and Development
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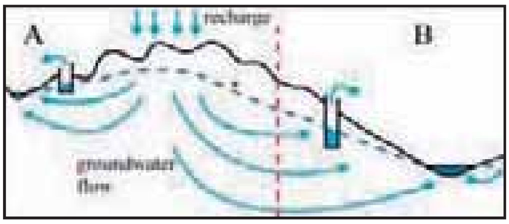
Issues to Consider

The concept of SGM is already embedded into the IWRM, yet it is often neglected due to a lack of awareness and know-how. Thus, the gathering, management and processing of data is one pillar of SGM. Profound assessments combined with applied research in multidisciplinary fields for setting-up calculations or groundwater models are a requisite for good groundwater governance.

Another pillar is the enhancement of communication and dialogue between various institutions and organizations on a national and transnational level. SGM often needs to be addressed on a transboundary level according to the hydrogeological boundaries of aquifers, which frequently cross political borders. As this may provoke discussions and conflicts over water rights and policies, cross-border cooperation shall be supported by peace-building measures, financing mechanisms and institution-building.



Exemplary sketch of a transboundary aquifer (UNESCO)

Groundwater Resources and Climate Change (www.groundwateruk.org)

Advantages

- Widely independent from short-term variations in precipitation and its immediate consequences for discharges or storage in open reservoirs
- Generally consistent chemical and microbial composition of water
- Allows for proper and timely interventions as water quantity or quality changes are detected early
- More cost-effective than aquifer restoration

Challenges

- Controversial demands on water resources have to be balanced: e.g. ecological (e.g. the conservation of wetlands) vs. economic (e.g. industrial water supply)
- Decreasing surface water resources threaten the water supply and increase the stress on the groundwater
- Affordability of high quality water for the poor is at risk as costs for water withdrawal (receding groundwater levels) and water treatment (increasing contamination) raise
- Bridging short-term surface water bottlenecks (e.g. due to seasonally dried-out rivers) by relying heavily on groundwater without damaging the aquifer

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River Basin Management (RBM)

... aims to adapt the human use of water resources to climate change while preserving natural functions

Definition and Objective

The ongoing **climate change** will affect the river basins around the globe. Changes in precipitational patterns, increased evaporation due to higher temperatures and the predicted increased occurrence of extreme events will directly influence the rainfall-runoff patterns and water balances in the basin, with related (quantitative and qualitative) effects on the aquatic and terrestrial environments, and the frequency of flooding or droughts.

River basins are complex systems comprising the total catchment (or watershed) area of the river system and associated surface and groundwater bodies as well as coastal waters. Any activities in the basin can have adverse effects on the status of water and its ecology, as well as having potential regional, social, environmental, and economic implications. Management practices that respond only to a single water use, a single population segment, or a single sector may disturb other uses, populations, and sectors. Therefore, all critical components need to be included into the planning process for the watercourses and their catchments. This approach is referred to as River Basin Management.

River Mulde, Germany (Elbe tributary)

River Basin Management (RBM) can be defined as a

"*process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems.*" (Global Water Partnership, 2000). The main objective of RBM is to establish a balance between the existing natural functions of the river system and the developed aspects of the system. The management actions should fulfil the expectations of the society for industrial use, recreation, nature management, and agricultural purposes.

RBM thus corresponds to the underlying principle of *"Integrated Water Resources Management (IWRM)"*. A similar term, "*watershed management*", is also widely used globally, often associated with projects for improved soil and water resources management (e.g. in sub-basins), essentially emerging from the agricultural / rural development perspective.

RBM in the European Union

The countries of the *European Union* are using the river basin approach for water management since the adoption of the EU Water Framework Directive (WFD) in 2000. **River Basin Management Plans (RMBP)** have been developed for most River Basin Districts (RBD) over several years and include the formulation of *Environmental Objectives* (e.g. "good ecological status", "good chemical status") and a *Programme of Measures (PoM)* to reach the objectives. According to the Planning Process of the *Common Implementation Strategy (CIS)*, the RBMP have to be updated every six years based on improved data and changes of circumstances in the river basins. Stakeholders and the general public must be consulted on their content, and the appropriate government minister must approve the plans.

Issues to Consider

RBM represents a *holistic and highly inter-disciplinary approach* that requires a comprehensive base of information about the river basin's hydrology, climate, ecological status/biodiversity, land use and agriculture, water use and wastewater discharge, industry/hydro-power as well as socio-economic pressures. The utilisation of different **tools, models and methods** is required, including *research models* (for simulation), *Decision Support Systems (DSS)* for policy-making and other support tools such as *databases and GIS* for spatial data management.

RBM requires setting up and maintaining comprehensive **environmental monitoring networks** within the river basins to calibrate the models, track the development over time and as a base for the subsequent planning cycle.

Water does not stop at country boundaries, and over 250 catchment areas worldwide are shared by more than two countries. Almost all large rivers of the world have **transboundary basins**. Close international cooperation between all riparian countries within the basin is required, to bring together all interests upstream and downstream. International Commissions or Basin Authorities have been established for major international river basins (e.g. Niger, Mekong, Danube).

Advantages

- Holistic approach covering the whole catchment area of a river according to the natural boundaries; inter-relates hydrological, ecological and socio-economic components of basins
- Basin-wide guidance from which specific actions in different fields of interventions can be delineated
- Mechanism through which water resources and demands can be balanced (thus avoiding long-term water scarcity); valuable tool for the management of flood risks in the catchments
- Cyclical nature of the RBM Planning suitable to adaptively manage climate change impacts, e.g. through re-calibration of models with changed data and updated climatic forecasts
- Foundation upon which the implementation of adaptation strategies and impact assessments can be realised

Challenges

- High information demand; complex
- Need for comprehensive and dense environmental monitoring networks, including the detection of climate change impacts
- Long planning process; strong need for participation of stakeholders and the public/public consultations
- Relatively high degree of aggregation
- Risk of enforcement problems in case of several involved authorities
- Transboundary cooperation, necessary for international river basins, adds degree of complexity

Transboundary River Basin:
River Sava, Balkans (Danube tributary)

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WATER
CLIMATE

Rainwater Harvesting

... serves as a freshwater source in regions which are drying out

Definition and Objective

Rainwater harvesting (RWH) is the accumulation and storage of rainwater for later use. Possible uses include agricultural production in arid and semi-arid regions, domestic supply, and environmental measures, e.g. the refilling of aquifers.

RWH systems have been developed primarily in areas where rainfall is not sufficient to support crop production or where water sources were scarce, of poor quality or inaccessible e.g. due to very deep groundwater. Numerous historic examples of RWH exist throughout the world, particularly in Northern Africa, the Middle East, Central Asia, and Latin America. Nowadays, RWH is often used as a tool to cope with climate change, more or less erratic rainfall, or extremely reduced surface water resources. RWH can also help to meet freshwater demands in regions which suffer from enhanced groundwater salinisation (caused by increased evaporation and less rainfall or by the intrusion of saltwater through rising sea levels). RWH can therefore be seen as a tool for resource diversification and is increasingly used in areas drying out due to climate change.

Types and Description

Technologies can be divided into two main areas: the in-situ and the ex-situ types of RWH. In essence, the in-situ technologies are soil management strategies which enhance rainfall infiltration and reduce the surface runoff. The ex-situ technologies are defined as systems which have separated catchment areas leading the water to the point of water storage. The most common ex-situ system is the rooftop rainwater collection.

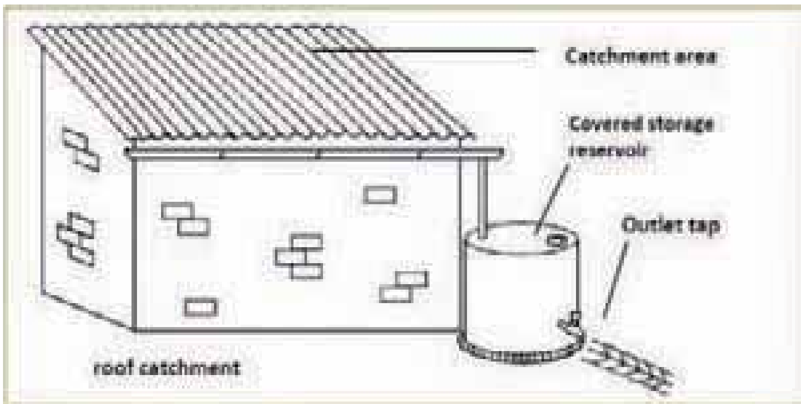
Typically, the in-situ systems do not cover a distance of more than 5-10 m from the point of water intake to the point of infiltration into the storage medium, mostly the soil. Often, in-situ RWH primarily serves the recharge of soil water for producing crops and other vegetation and reducing the need for irrigation. In-situ RWH can also be used, e.g., for recharging shallow groundwater aquifers and/or supplying surface waters. Often, in-situ RWH is based on a range of soil conservation measures, such as terracing, pitting, and conservation tillage practices, which are commonly implemented to counter soil erosion.

Ex-situ systems include catchment areas with usually low or little infiltration capacities like, e.g., rooftops, roads or pavements; yet also bits of ground or rocks are used. These catchment areas allow for a fairly easy collection of substantial amounts of water. This is then stored in wells, dams, ponds or cisterns and, when needed, abstracted and distributed for irrigation or domestic, public and commercial uses.

RWH: Fetching water from a dry river bed in Mozambique (Chang, UNEP, SEI, 2009)

Issues to Consider

- First flush (first water of rainfall) must be separated to avoid drinking water contamination
- Prevention of microbial contamination
- Soil conditions as catchment area and/or storage
- Suitable storage medium, adapted to use
- Precipitation data of the area is required to calculate the needed catchment area and size of storage facilities
- Runoff structures in case of full storage



Schematic of a RWH system by UNEP IETC, 1998 (www.climatetechwiki.org)

Advantages

- Proven benefit with low environmental impact
- Low construction and running costs
- Easy to install and operate
- Usually readily available construction material
- Low-tech, flexible installations
- Less runoff of clean rainwater to wastewater treatment plants
- Decentralised water storage
- Reduction of soil erosion (in situ)
- Promotion of self-sufficiency and of diversification of agricultural production
- Additional freshwater resource
- Powerful tool to increase resilience towards climatic changes

Challenges

- Bridging dry periods while depending on an unreliable source and limited storage capacity
- Mitigating the depletion effect on water sources and ecosystem services (ex situ) with possible conflicts (downstream or within communities)
- Potential vector breeding habitat (e.g. for mosquitos)
- In communally owned systems, a RWH-committee has to be created in order to ensure maintenance
- Consideration of climate related risks (floods, winds)
- Subsidies may be required for poorer households
- Clear property rights needed

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WATER
CLIMATE

Preservation of Ecosystem Functions

... serves adaptation to climate change by sustainably utilizing natural ecosystem services

Definition and Objective

Ecosystems are dynamic complexes of plant, animal and microorganism communities and the nonliving environment interacting as a functional unit. Ecosystem services are the benefits people obtain from ecosystems.

Category	Example
Provisioning	Food, fresh water, wood, fibre, fuel
Regulation	Climate, water quality, floods, disease
Supporting	Soil formation, photosynthesis, nutrient cycling
Cultural	Aesthetic, spiritual, recreational

Categorisation of ecosystem services

Using an ecosystem services approach in adaptation to climate change is not about adapting the ecosystem, it is more to use the adaptive potential of the ecosystem for the sake of humans. The concept is also used to illustrate the dependency of the human environment with the natural sphere.

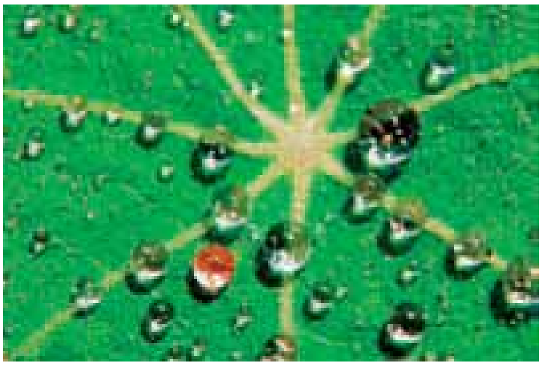
As the resilience and adaptation capacity of ecosystems to climate change impacts is higher when they are intact, preservation should be a central point.

Of special interest in ecosystem preservation are areas with high biodiversity. The term biodiversity describes the diversity of life on earth and encompasses genetic diversity, species diversity and diversity of ecosystems. It can help to mitigate climate change, e.g. tropical rainforests by storing greenhouse gas emissions. Furthermore it supports adaption to altered environmental conditions, like offering new varieties of crops better adapted to drought conditions.

Since the middle of the 19^{th} century biodiversity has declined by 75 percent. To preserve biodiversity and its functions, as well as to use it sustainably, and to share fair and equitable benefits of genetic resources, the United Nations Conference on Environment and Development set up the Convention on Biological Diversity (CBD) in June 1992.

Types and description

Protection measures for ecosystem services can be split into conservative and preservative measures. Preservation in the narrow sense leaves natural areas on their own in total self-regulation. Conservation still includes regulating interventions like reducing predators or controlling invasive species. It also can include a sustainable use of natural resources from within the conserved area.



- Expanding protected areas and ecological networks
- Strengthening capacities to survey and report on protected areas
- Enhancing efforts to identify drivers of water biodiversity degradation
- Voluntary payment schemes for ecosystem services
- Biodiversity considerations in IWRM and regional development plans
- Sustainable use of groundwater and reduction or replacement of chemical fertilizer
- Protection of natural water flows from straightening or cutting of connections

Possible Steps to be taken for preservation of ecosystem services

Issues to Consider

- Identification of important focus areas and tradeoffs
- Analysis of the vulnerability of ecosystems to climate change
- Economic assessments of ecosystem services
- Focus on sustainable use of natural resources to raise acceptance of protected areas
- Co-management by local (and indigenous) stakeholder groups with inclusion of local knowledge
- Creation of alternative sources of income to reduce pressure on ecosystems
- Environmental education and information dissemination
- Maximizing the natural adaptive capacity of diverse ecosystems by reducing other threats such as overuse and pollution
- Combination of ecosystem-based approaches with sector-specific approaches (i.e. restoration of wetlands & fish ponds for food security)
- Integration of the private sector, e.g. green sponsoring
- Cross-border approaches to protect ecosystems in their entireness (integrated coastal area management, transboundary river basin cooperation)

Advantages

- Enhances the adaptation potential to climate change, e.g. ensuring drinking water quality and quantity
- Often more cost-effective in comparison to infrastructure or flood control measures
- Allows simplification of complicated biophysical system and focus on key ecological processes
- Enhanced resilience of ecosystems to climate change

Challenges

- So far, the internationally agreed commitments of CBD and other environmental agreements have scarcely been put into practice
- Control of protection measures needed

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Irrigation technology and methods

... enable farmers to adapt to water scarcity and thus ensure agricultural production

Definition and Objective

Climate Change will have a significant impact on agricultural water management. It is predicted that rainfall and temperature will become more variable. In many regions, precipitation will become less predictable, heavy storms as well as droughts will occur more frequently. This will lead to increased water demand and reduced water supply. Consequently, large scale land use change is expected on all continents.

40 % of the world's food from an estimated 20 % of agricultural land (about 300 million ha) are produced by irrigated agriculture. Due to climate change, the share of irrigation agriculture will become larger and more efficient irrigation technologies will become increasingly important. Since irrigated agriculture is the largest water consumer (up to 78 % of the fresh water volume) in some countries, the introduction of water saving technologies and methods will have an enormous impact on the productive use of the water resources that became scarcer. A range of irrigation technologies and methods have been developed and adapted to match the different combinations of soil condition and crop choice. They are excellent tools for adaptation to the effects caused by climate change.

In surface irrigation systems, water moves over and across the land by simple gravity flow in order to infiltrate into the soil. Surface irrigation can be subdivided into furrow, borderstrip and basin irrigation and is often called flood irrigation. Historically, this has been the most common method of irrigating agricultural land.

Localized irrigation is a system where water is distributed under low pressure through a piped network, in a pre-determined pattern, and applied as a small discharge to each plant or adjacent to it.

Drip irrigation, spray or micro-sprinkler irrigation and bubbler irrigation belong to this category of irrigation methods. In drip irrigation systems, (also known as trickle irrigation) water is applied drop by drop just at the position of roots. This method is the most water-efficient method of irrigation, if managed properly, since evaporation and runoff are minimized. In modern agriculture, drip irrigation is often combined with plastic mulch, further reducing evaporation, and is also the means of delivery of fertilizer. The process is known as fertigation. In sprinkler or overhead irrigation, water is piped to one or more central locations within the field and distributed by overhead high-pressure sprinklers or guns. Sprinklers can also be mounted on moving platforms connected to the water source by a hose. Automatically moving wheeled systems are known as travelling sprinklers.

Low energy systems (LEPA: Low Energy and Pressure Application) have been developed for use with lateral move and centre pivot systems, both to reduce pumping costs and to minimize wind effects on application uniformity. Centre pivot irrigation is a form of sprinkler irrigation consisting of several segments of pipe joined together, mounted on wheeled towers with sprinklers positioned along its length. The system moves in a circular pattern and is fed with water from the pivot point at the centre of the arc. These systems are found and used in all parts of the world and allow irrigation of all types of terrain.

Sub-irrigation is a method of artificially raising the water table to allow the soil to be moistened from below the plants' root zone.

Issues to Consider

Selection of appropriate irrigation technology and method depends mainly on factors like type of crop, type of technology, previous experience with irrigation, required labor inputs, costs and benefits.

In conclusion, surface irrigation is normally used when conditions are favorable: mild and regular slopes, soil type with medium to low infiltration rate, and a sufficient supply of surface or groundwater. In the case of steep or irregular slopes, soils with a very high infiltration rate or scarcity of water, sprinkler and drip irrigation may be more appropriate. Evaporation of irrigating water may lead to salinisation of soils. Therefore, appropriate drainage systems should be installed with irrigation. On the cost side not only the construction and installation, but also the operation and maintenance (per hectare) should be taken into account The trend is clearly towards water saving technologies (drip, sprinkler, etc.) according to the guiding principle: “more crop per drop”. Water saved in agriculture can then be made available for other sectors e.g. human consumption, industry, tourism and environment.

Advantages

- Surface irrigation systems - in particular small-scale schemes - usually require less sophisticated equipment for both construction and maintenance (unless pumps are used)
- Sprinkler and drip irrigation require little land leveling; system operation and maintenance are less labor-intensive
- Fertigation is more efficient and easier to manage in pressurized systems
- Water application efficiency is higher with sprinkler and drip irrigation than surface irrigation; these methods are preferred when water is in short supply
- Surface irrigation is preferred if the irrigation water contains much sediment. The sediments may clog the drip or sprinkler irrigation systems.

Challenges

- High degree of technical know-how should be available, especially for drip and sprinkler irrigation
- For surface irrigation a much higher labor input - for construction, operation and maintenance – is required compared to sprinkler or drip irrigation
- High capital investment per hectare has to be made to purchase equipment (especially for sprinkler and drip, which are profitable primarily for high value cash crops)
- Surface irrigation requires accurate land leveling, regular maintenance and a high level of farmers' organization to operate the system.

Drip irrigation and center pivot irrigation (AHT)

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WATER
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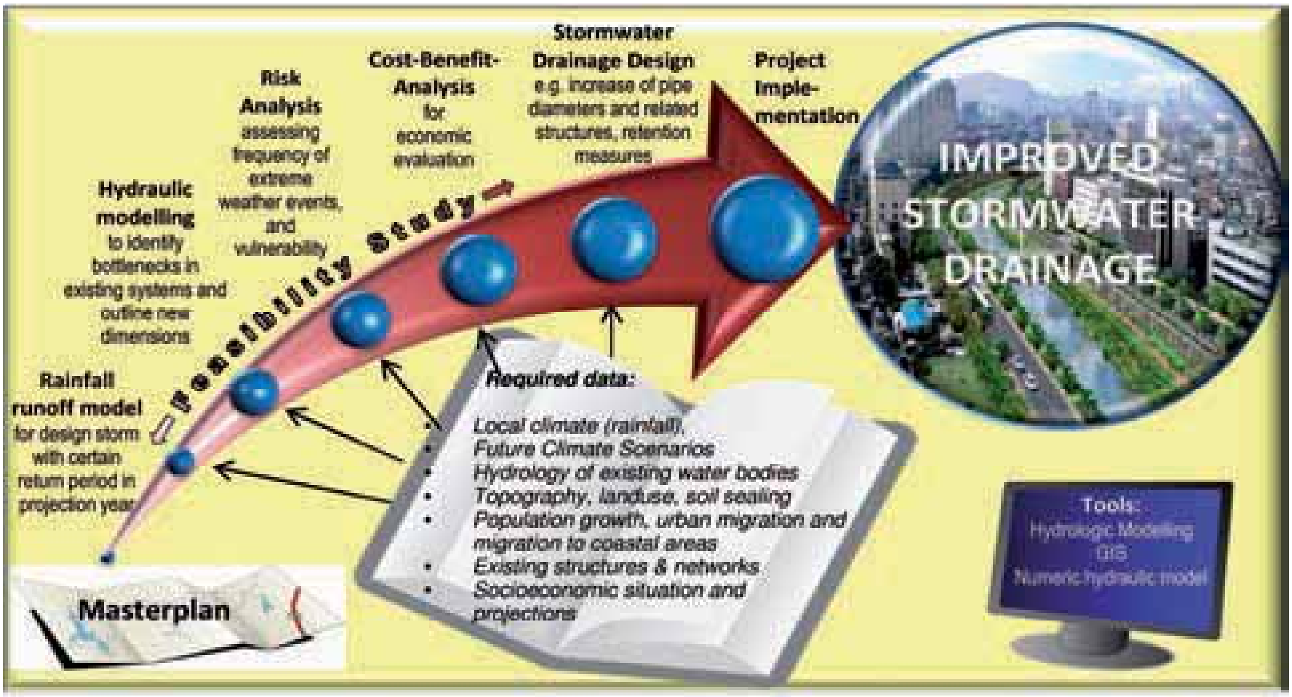
Improved Stormwater Drainage

... mitigates or prevents climate change impacts (runoff peaks, flooding of cities)

Definition and Objective

The ongoing climate change entails modified weather patterns regarding rain frequency and intensity, temperature, and snowmelt; but also the sea levels in coastal areas are affected. Extreme weather events, such as thunderstorms and cyclones, have increased significantly in recent years and are likely to occur even more often in the future. A major result is more frequent flooding with significantly higher peaks. As a result, existing drainage systems are undersized and cannot accommodate increased runoff peak flows and volumes. The proper functioning is however essential for health and safety for all beings, and prevention of severe economic damages and losses. Developing countries are particularly at risk, due to a high vulnerability to climate change impacts and weak adaptation capacities. Innovative stormwater management concepts - as part of an Integrated Water Resources Management (IWRM) - can not only mitigate climate change impacts, but have the potential to address water supply challenges of cities.

Consequently, climate change considerations have to be factored into identification of priority investments and need to be closely considered in planning, management and operation of infrastructures. The achievement of improved stormwater drainage systems includes many multidisciplinary tasks, as shown in the figure below.



Tasks for improved stormwater drainage at Feasibility Study level (CES)

Issues to Consider

Several, non-consistent global climate models with different scenarios exist. Whereas global models may be quite reliable for global scenarios, regional and in particular local climate projection data are currently very fractional. Until relevant scenarios are downscaled to serve for the assessment and design of storm water systems, tools such as inter- or extrapolations of data are to be used, even if harbouring large uncertainties. It is hence challenging to define adequate design parameters and to accommodate the "climate factor" in a sound way. It has to be kept in mind that measures should be able to cope with changes for many decades, and that manifold developments (such as population and land use) play an important role. Further, integrated WRM techniques, such as stormwater harvesting, infiltration (to restore the natural recharge of groundwater) or bio-retention (e.g. rain gardens) need to be considered in urban development planning.

Advantages

- Protection of life and health (especially avoidance of water borne diseases)
- Economic benefits by prevention of cost of flood damages (property, infrastructures, treatment of polluted environment, and socio-economic costs, such as loss of earnings)
- Entry of pollutants, nutrients, hazardous substances from urban areas into water, soil and air can be avoided, and water resources preserved
- In cities with combined storm and sewage systems increased amounts of sewer overflow can be avoided due to improved drainage capacities
- Use of storm water harvesting technologies: relieve the drainage network, reduces the amount of water that can cause flooding and can serve as additional water resource (see also Factsheet "Rainwater Harvesting")

Challenges

- Definition of adequate design parameters, application of sustainable climate data, and prudent interpretation of modelling results
- Increasing population, urbanization, migration to coastal areas, and advancing soil sealing to be considered
- Economic considerations: higher investment and maintenance costs for incorporation of the "climate factor" versus projected damages due to increasing floodings
- Capacity building of actors to be involved in storm water management
- Changing morphology and discharge capacity of receiving water bodies due to climate change induced hydrological changes to be allowed for

Flooded city (CES)

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WATER
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Flood Sensitive Planning

...supports authorities in reducing a population's vulnerability to climate change impacts (floods)

Definition and Objective

As a consequence of climate change, storm and flood events in coastal and river areas will occur more frequently and are still difficult to predict. Coastal cities are especially at risk when heavy rainfalls or river floods coincide with storm waves of tropical cyclones and gradual sea level rise. Flooding in cities harms people's lives and livelihoods, hurts the economy and damages the basic infrastructure, e.g. for water and sewage, communication, health and transportation. Furthermore, floodings may open pathways for pollutants, pathogens and salt water to diffuse into the urban water supply system and thus harm human health, livestock and urban ecosystems.

Poor people are especially vulnerable to flood damages due to their often exposed settlements, heavy reliance on subsistence farming and fishing, fragile natural resource base, malnutrition and, in general, poor health conditions.

The vulnerability of the (poor) population in risk areas can be reduced by applying flood-sensitive planning. This tool can also extend the lifetime of infrastructure in these areas and thus bring economic relief.

Types and Description

Flood-sensitive planning aims to integrate an assessment of the challenges and opportunities aligned with the climate change impacts on river and coastal zones into a respective action plan. This action plan is then to be broken down to different levels (national, regional, local and sectoral). In addition, the selected actions have to become part of the sector planning and respective budgeting in order to guarantee the financing.

The basic elements of this tool are climate change adaptation measures. The selection and combination of useful measures can be supported by the Toolbox for Climate Change and Adaptation in the Water Sector and by applying the "climate proofing" methodology developed by GIZ.

The following key questions can help to identify those elements which are particularly affected by climate change and can thus facilitate the planning process:

- Do climate trends, such as increasing temperatures or sea level rise, have a potential relevance for planning? If so, of which kind are the specific impacts (intensity, time of occurrence, frequency?)
- Does the time horizon of the planning correlate with that of the climatic trends? (short-, medium- or long-term planning horizon)
- Does the planning refer to elements (exposure units) which are particularly affected by climate change (e.g. sectors, policy aspects, geographic area, specific target groups, etc.)?

→ More information about climate proofing:

Climate Proofing for Development

Adapting to Climate Change, Reducing Risk

http://www2.gtz.de/dokumente/bib-2010/gtz2010-0714en-climate-proofing.pdf

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Issues to Consider

The application of a multi-level approach is strongly recommended for all types of climate-sensitive planning, including the one described above, as it ensures a coordinated and efficient proceeding. This accounts for the national, regional and local and, if applicable, also the project level. In addition to the multi-level proceeding, the sectoral coordination on the same level needs to be enhanced, as it otherwise may be a stumbling block. The creation of inter-sectoral structures is required in order to determine the tasks and roles of the institutions involved in the planning process. Furthermore, the planners have to set-up and communicate the mechanisms of financing climate adaptation measures to allow for a smooth performance on all levels.

The integration of the local level is particularly crucial for the development of successful adaptation measures in urban areas. Climate change affects local livelihoods and the surrounding environment. Thus, the degree of climate vulnerability is determined locally and options for action are often best identified at local level. Fields of action include infrastructure (e.g. dams), building legislation (especially concerning illegal settlements), drainage of flood water and the creation of natural retention areas.

Advantages

- Saves lives
- Improves hygienic situation
- Protects drinking water from contamination
- Reduces damage to infrastructure
- Reduces economic damage

Challenges

- Possible conflicts over use of space between flood-sensitive planning and alternative use (i.e. inundation area vs. settlement area)
- Additional costs for more complex planning processes and additional techniques and measures
- Raising awareness of vulnerable, local communities requires time and resources

Integration of local people into the planning processes (PRO-GRC, 2011)

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WATER
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Economic Incentives for Ecosystem Protection

...contribute to the adaptation to climate change by fostering environmentally responsible behavior

Definition and Objective

By definition, an ecosystem is an interacting system that encompasses a community of living organisms of varying species (animals, plants, microbes) and its "nonliving" environment like water, air and mineral soils. Ecosystems are in general significantly complex and as such extremely vulnerable to the impacts of climate change, global warming and overexploitation. Measures have therefore to be taken to safeguard sustainability of the systems.

This applies particularly to aquatic ecosystems. In a global sense, changes in and deterioration of aquatic ecosystems are predominantly results of man-made factors such as water consumption, pollution etc. These may, however, be aggravated by climate change through changes in precipitation, temperature rise, etc. Changes in ecosystems have obviously a decisive impact on living conditions of populations that use natural resources like water in its many different facets. Such changes call for action, i.e. protection, mitigation and adaptation. Different approaches must be applied under consideration of locally prevailing conditions. The fact that particularly developing countries are most threatened by climate change shows the increasing pressure for action and the need for solutions. The goal is to improve the use of existing resources, to adapt to changes and to reduce environmental side effects of resource use. Mechanisms that promote efficient use of resources, sustainability and improved allocations are necessary.

Basically two types of instruments for control of ecosystems exist: in the past almost only traditional regulatory approaches were used that stipulate specific standards that stakeholders have to comply with. The creation of economic incentives played a subordinated role only. However, the use of economic inducements and market forces to control the stakeholder's behavior provides substantial advantages and is therefore given increasing attention. Economic incentives can be applied to a wide range of issues on various economic levels and target groups, be it corporate institutions, producers or consumers. Types of market based incentives can be seen in

- Tariffs, fees and charges (e.g. monetary incentive on reduction of consumption or pollution)
- Subsidies (e.g. rewards for reducing detrimental impacts)
- Marketable permit systems (capped or uncapped trading systems)

Typical measures focusing on the creation of economic incentives include

- Appropriate water and wastewater tariffs inducing water conservation behavior, requiring comprehensive consumption metering water supply networks
- Adaptation of crop patterns to changing conditions
- Modification of production processes to reduce consumption of water, energy and discharge of pollutants
- Reduction of technical and administrative water losses
- Increase of managerial, operational and financial performances of stakeholders, in particular water producers and utilities

Combinations of such measures can be applied in order to maximize benefit. The focus must be on more efficient and sustainable management of resources.

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Issues to Consider

Progressing effects caused by climate change and unprecedented population growths in developing countries increase pressure for action. In order to assure success of economic incentives related measures need to be properly designed and tailor-made solutions on the basis of the prevailing conditions need to be sought. Potential measures need to comply with the legislative framework which may have to be adjusted for this purpose. Social compatibility and acceptance by the stakeholders must be assured. Rising public awareness and due considerations of abilities and willingness to pay of consumers are prerequisites. In case of institutions, implementation of incentives needs to be accompanied by proper capacity building measures to assure viability of cross cutting functions. Studies and appropriate design of the measures need to be safeguarded.

Advantages

- Provision of continuous inducement does not stop when regulated levels are achieved
- Benefits can be generated as long as financially viable
- Incentives go along with the creation of public awareness for sustainability issues and provide potential enduring improvements
- Incentives foster socially responsible behavior
- Business risks are reduced, business opportunities are created
- Human well-being and public health are improved
- Competitiveness and public perception of industrial and commercial entities improve as a result of better environmental behavior
- Combination of regulatory standards and economic incentives possible
- Reduction of liabilities of polluters

Challenges

- Cultural and socio-cultural conditions need to be taken into account
- Public awareness, acceptance and the will to support adaptation must be assured
- Environmental long-term policies integrating all relevant sectors need to be in place
- Existing laws and regulations may need to be adjusted
- Complexity, interactions and sensitivities of concerned ecosystems must be regarded
- Implementation of measures must be monitored; and approaches for emerging problems must developed
- Efficiency of incentives need to be supervised, measures to avoid abuse must be considered and fraud sanctioned

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WATER
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Ecological restoration

...uses ecosystem services to adapt to climate change impacts

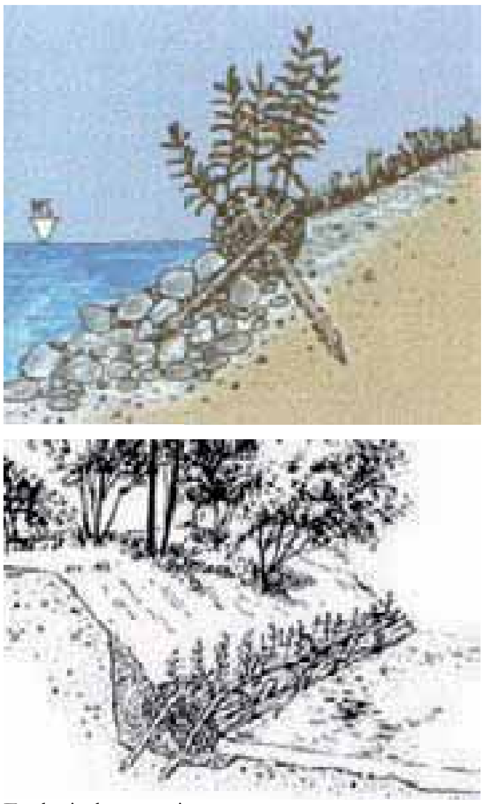
Definition and Objective

Ecosystem services offer a chance for adaptation to climate change. These services are the benefits people obtain from ecosystems, like cleaning and storage of drinking water. For using these services more effective and sustainable, they have to be in a viable state. Many ecosystems are already degraded and damaged through human interference. Degraded rivers e.g. are characterized by high fluctuation of discharge, people living in the riverbanks, or intensive changing of river morphology etc.

Ecological restoration assists the maintenance or even creation of ecosystem services by fostering the recovery of a damaged or destroyed ecosystem. Restoring water bodies enhances the adaptation potential of the water sector to climate change.
Restoration projects can largely vary in scale, starting with simple re-vegetation on river banks, till complete reconstruction of the natural, meandering river bed. It may depend on the environment, objective and current use of the water body which restoration option is possible.

Types of ecological restoration

- Determining the normal hydrology of the restoration side
- Restore eroded riverbank using vegetation and bioengineering technology
- Re-vegetation using appropriate plants with strong roots to prevent erosion
- Use bio-engineering tools like bamboo fence or gabion to gain new river bank or hold soil for vegetation
- Restore the aquatic habitat, e.g. install recreational areas
- Maximizing dam passage to allow recovery of fish meta-population structure
- Extirpation of damaging species
- Re-naturalisation of flow regime by remodelling topography and excavation
- Reduce the tendency of community to live in riverbank areas
- Revise and adapt land use plans



Ecological restoration measures

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Issues to Consider

- Examination of water quality in focus of hazardous material to ensure quality of groundwater
- Suitable and local vegetation in the right amount
- Planting only if natural re-colonisation fails, especially for mangroves
- Look at the potential existence of stresses such as blocked tidal inundation
- Consultation and involvement of local people
- Planning and design based on an understanding of geo-morphological and ecological processes, rather than simply mimicry of form
- More likely to be successful if undertaken for whole watersheds
- Takes long time till restored area can be compared in biodiversity and ecosystem services with an intact, untouched ecosystem.

Advantages

- Increased provision of biodiversity and ecosystem services
- Enhances the adaptation potential to climate change
- Often more cost-effective in comparison to infrastructure or flood control measures
- Natural regeneration can be cheap
- Flood defense by installation of natural retention areas

Challenges

- Lack of scientific knowledge of watershed-scale process dynamics
- Lack of political support
- Less usage of water body resources after restoration
- Restoration is just a step, protection has to follow

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WATER
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People-centered Early Warning Systems

...help the population cope with the climate change-induced higher frequency of flood events

Definition and Objective

As a consequence of climate change more erratic and extreme rainfalls, an increasing number of tropical cyclones and rising sea levels will cause frequent and hardly predictable flood events. Especially developing countries such as Bangladesh, the Philippines, Indonesia, Madagascar and Mozambique have limited capacities to cope with those extreme events.

Early warning systems help to mitigate countries' susceptibility to climate change impacts by reducing their vulnerability to extreme events and therefore minimizing the risk for people's lives and livelihoods.

Low cost, people-centered early warning systems in which Disaster Risk Reduction committees (DRR committees) play a leading role provide crucial development opportunities for least-developed countries. Pioneering work has been done in Mozambique, where, commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and Munich Re Foundation, the simple and effective Búzi Early Warning System was developed. The best-practice model for people-centered early warning systems in the Búzi river basin uses a simple approach: local DRR committees are trained to monitor the river levels and send data to the district capital Búzi, where it is analyzed by the Technical Council for Disaster Risk Management – a body representing different sectors, including agriculture, education, health and infrastructure planning. When water levels are critical, the Operative Emergency Centre is activated and a radio warning is sent to local communities at risk. In each local DRR committee, the member who is responsible for monitoring the radio passes information on to those in charge of the early warning. Using text messages, megaphones, drums and local radio broadcasts, they spread the message within their community. This ensures that even illiterate members of the community are also informed on time. Having previously been trained by the DRR committee, the community then knows how to respond. The members of the evacuation team use risk maps, which have been developed in a participatory process, to bring the community to safer grounds.

Members of the Disaster Risk Reduction committee responsible for Early Warning (Thomas Loster, MRS)

For more information, go to:

http://www.youtube.com/watch?v=2oBqJ7csSO0

Issues to Consider

In order to empower the government and civil society to cope with multiple current and future hazards, early warning systems should be focused on:

1.) Human resource development
Advising and strengthening of national institutions and civil society

2.) Organizational development
Creating a disaster prevention and emergency structure, working with local DRR committees

3.) Network development
International exchange of experiences, for example within South-South Cooperations

4.) Institutional development
Laws and regulations for Disaster Prevention and Climate Change Adaptation

With the help of local disaster prevention committees, even people living in remote areas can be evacuated safely before heavy flooding threatens their lives

Advantages

- In-time evacuation to safer grounds
- People-centered early warning systems save lives and prevent injuries
- Flood-affected communities organize evacuations without any external help (empowerment and decentralization)
- DRR Committees raise awareness for and inform their communities about disaster mitigation and preparedness measures
- Low-cost technology which can be run by local people

Challenges

- Mitigation and prevention measures (especially maintenance costs) have to be integrated in local district budgets
- The information flow and emergency response have to be exercised regularly in order to guarantee their functioning in emergency cases
- Awareness-raising and consolidation of local DRR committees need several years to break with unsafe behavior
- Long-term data-monitoring systems have to be established

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WATER
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Desalination

... provides potable water where freshwater supply decreases due to climate change

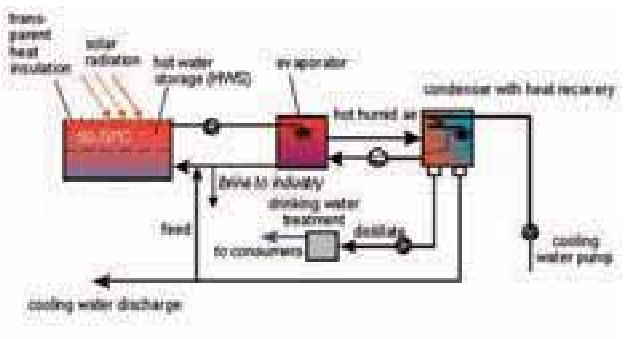
Definition and Objective

The water treatment process that separates salt from saline water to produce water that is low in total dissolved solids (TDS) is called desalination. This desalination process facilitates the production of potable water from salt water or seawater as well as brackish water. Several methods are available to decrease the total dissolved solids.

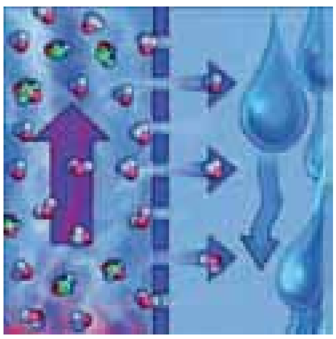
Main objectives of desalination are a diversification of the water resource and an increase in drinking water supply especially in regions where groundwater resources are limited. Diversification of water resources can enhance the capacity to deal with upcoming shortages of water caused by climate change.

Types

	Power source	Scale of projects
Thermal methods		
Solar Stills	solar energy	for small scale
Vapour Compression (VC)	electricity	small to medium
Multiple Stage Flash (MSF)	heat	medium to large scale
Multiple Effect Distillation (MED)	heat	medium to large scale
Membrane methods		
Electro Dialyses (ED)	electricity	only used for brackish water
Reverse Osmosis (RO)	electricity	appropriate for any scale



Thermal desalination plant with solar power
www.dwc-water.com



Reverse Osmosis membrane
www.mechanical-writings.com

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Issues to Consider

The implementation of a desalination plant involves several points that have to be considered. A feasibility study and a pilot project are recommended to ensure that negative side-effects are attenuated. Implementing a desalination plant requires the corresponding technology depending on the method proven to be most suitable. Intake and conveyance structures are necessary to guarantee a permanent supply with source water. Site specific source water quality and quantity often influence the desalination plant type and the intake structures.

The extracted raw water has to be pre-treated to prepare the source water for further processing. During the pre-treatment suspended solids are removed and biological growth is controlled. After the desalination process post-treatment of the water is necessary to protect infrastructure against corrosion and to avoid introduction of metals into drinking water.

Of particular importance in the desalination process is the concentrate and residuals management.

Advantages

- Modular construction: expansion of facility easy
- Diversification of water resources
- Reliable source of potable water – seawater independent from weather
- Local control over water supply
- Production of high quality water

Challenges

- Cost-intensive implementation
- High energy demand
- High maintenance costs and knowledge
- Environmental impact through concentrate disposal
- Mostly applicable to coastal areas

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WATER
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Dams and reservoirs

... are multifunctional responds to climate change impacts (floods, drought)

Definition and Objective

Dams are man-made barriers across a water body to control the flow or raise the level of water. They are mainly multipurpose systems aiming at and ranging from storage for irrigation and water supply, flood prevention, hydro power generation, navigation to tourist attraction and aquaculture..

In case of a failure of such a structure immense damages to economy and beings must be expected. In consequence, the parameters outlining the dimension, design and operation are laid out in detail in numerous norms and guidelines. The safety regulations are based on statistical determination of existing data sets derived for flood events of probabilities from 1 to 1,000 up to 10,000 years.

Under the influence of climate change, dams and reservoirs will become increasingly important. On the one hand, hydropower is one of the major renewable energy technologies and dams and reservoirs can additionally be used as storage medium for variable renewable energy sources. On the other hand, dams increase the capacity to deal with severe extreme weather events by offering run off storage and stored water in times of drought.

Dams and reservoirs address expected water scarcity and thus are one of the priorities for climate change adaptation. Water stored in multipurpose dams can be provided in times of scarcity or drought for drinking water supply, agricultural, industrial, environmental and human needs.

Due to more extreme and changing precipitation patterns, precipitation variability will increase across all regions. The loss of glaciers and snowpack mean that natural water flows are going to become more variable. More and larger dams could help to smooth out that flow. In consequence, the assessment of environmental and social impacts must be investigated more intensively.


Comarapa dam, Bolivia (CES)

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CES Consulting Engineers Salzgitter GmbH

Issues to Consider

Although climate change will influence rainfall patterns, etc., it is expected that relevant design flows of low probability (<1:1,000) will not be influenced by current climate projection and thus the safety of the structures will not be endangered. Flows of higher frequency will increase and a seasonal shift is to be expected. Flood risk assessments have to take these changing flows into account.

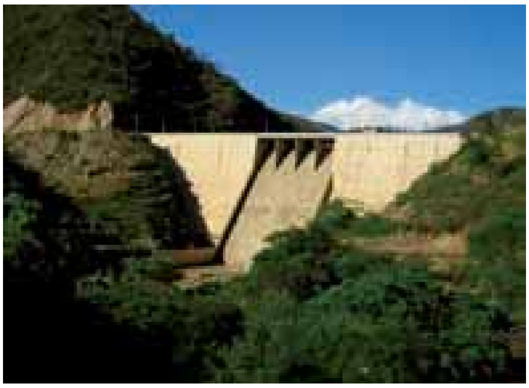
The management and operation of existing and future dams and reservoirs must consider several aspects that might be triggered by climate change. Structures must be designed and operated in order to react flexibly to changing boundary conditions.

Physical modification of land use in the catchment areas will change the sediment load and chemical content in the water. As the number of dams is increasing, it is especially challenging to preserve the ecological passability of rivers (e.g. by installing fish passes). Higher temperatures will increase evaporation losses from lakes and reservoirs, thus impacting storage capacities, and may furthermore influence the micro-climate. These aspects will change the ecosystem of a reservoir. Additional biomass could be generated and lead to an increased emission of greenhouse gases.

In the future, an integrated water resource management taking into account more intensely all climate sensitive parameters and factors will become increasingly important.

Advantages

- Electricity generation and storage
- Contribution to economic growth
- Flood protection and management
- Water supply for industry and households
- Irrigation/Food security
- Establishment of recreational areas and promotion of tourism
- Improvement of aquaculture



Comarapa dam, Bolivia (CES)

Challenges

- Morphological transformation of rivers
- Impact on riverine ecosystem (flora and fauna)
- Social and legal consequences (displacement, loss of access to resources)
- High construction expenses
- Production of greenhouse gases due to biomass versus renewable energy generation
- Prevent the promotion of diseases (e.g. bilharzias or malaria) through created lakes and wetlands
- Consideration of environmental flow and ecological passability versus use of water resources
- Strengthening capacity for integrated water resource planning and management
- Adaptation of technical design for more flexible structures such as spillway, outlets

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WATER
CLIMATE
Toolbox

Climate Monitoring and Prediction

... are prerequisites for the planning of climate change adaptation measures

Definition and Objective

Climate monitoring and prediction (CMP) is turning into one of the main pillars for developing countries to cope with climate change. CMP delivers data for the adaptation of livelihoods to future conditions and can thus be seen as a planning tool for the macro, meso and micro level. CMP can be applied in various contexts like infrastructure planning and building, housing, disaster risk management, agriculture, or coastal zone management. Yet, CMP methods and techniques vary considerably in price, complexity and focus, which makes it a challenge to choose the appropriate technology.

Types and Description

CMP methods can be divided into three groups: 1) practices measuring surface and subsurface elements, 2) practices measuring upper atmosphere elements, and 3) practices based on remote sensing. Each of the three groups should be applied by following the standards of the "Guide to Climatological Practices" by the World Meteorological Organization (WMO, 2011, third edition).

The first group's spectrum ranges from simple measurements with regard to, e.g., temperature or precipitation to a broader variety of phenomena (like humidity, atmospheric pressure and radiation) or to marine observations concerning biochemical (dissolved oxygen, etc.) or physical and chemical elements (e.g. salinity, sea level, etc.). The constant gathering and provision of data on one particular factor which reflects the essential characteristics of the respective area can be decisive in ensuring an effective forecasting, planning and sometimes even warning: e.g. the hydrological conditions for areas prone to flooding or droughts. The second group of practices concerns the measurement of upper-air elements, e.g. temperature, air pressure, radiation and the chemical composition in different layers of the atmosphere. This practice is of major importance in climate change monitoring, climate and air-quality prediction. The third group - the remote-sensing measurement of e.g. the albedo, sea surface and atmospheric temperatures - is advantageous in data-sparse areas and with regard to spatial and temporal coverage. Nonetheless, its homogeneity and lower accuracy only makes it complimentary to surface measurements.

The gathered data is then usually processed by applying computer models, which range from highly complex to quite simple versions based on empirical or statistical relationships. These models are used to produce climate outlooks, i.e. climate predictions or climate projections. Climate predictions are based on the known current conditions and derived by applying assumptions regarding future physical processes. Climate projections explicitly allow for changes in the setting of boundary conditions. The best-known ones are the Assessment Reports published by the Intergovernmental Panel on Climate Change (www.ipcc.ch).

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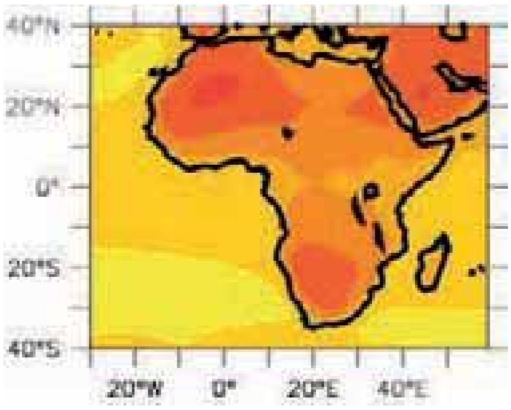
Issues to Consider

Within the context of International Cooperation, climate predictions are the most important tool for planners, as they provide information on the changes which are to be expected. It is important to choose easy-to-use climate models in order to get comprehensible, clear outlooks and thus allow planners and decision makers to draw conclusions and take respective actions. In addition to the simplicity of the design, further criteria to select the appropriate practice and instrument are a) the reasons for making observations; b) the required accuracy; c) the suitability for the operational environment; d) the reliability and e) the acquisition and maintenance costs. The prevention of costs is another major objective in this context and can be achieved by carefully planning the climate monitoring network (e.g. the placement of climate stations) as well as the concept for data management from the very start.



Modeling Future Climate on a Regional Scale by the National Earth Science Teachers Association Windows to the Universe (www.windosw2universe.org)

The benefits of this highly time and cost-consuming process can be maximized by feeding in the gathered data into the WMO network for world-wide use (www.wmo.int). The other way round, large scale data is downscaled to regions - mostly by using regression methods - in order to generate locally relevant data. The thus generated data are estimates only, but often provide the most useful outlook available.

Advantages

- Provides data for climate change prediction and thus for an effective long-term forecasting and planning
- Data is a key factor to infrastructure building and agriculture (short and long-term)
- Powerful tool in disaster risk management, mainly regarding disaster prevention and risk reduction
- Climate information for international negotiations and agreements

Challenges

- Preparation and dissemination of information to users and decision makers
- Close the gap between climate prediction and political action
- High price differences, as some methods are based on highly sophisticated technology
- Quality control of the data has to be done regularly
- Information with high resolution is required for the application at the micro level, which the global and regional climate models generally do not provide

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Climate Education

... raises awareness about the impacts of climate change and teaches options for adaptation

Definition and Objective

Climate change will lead to increased water scarcity and an increased frequency of disasters, such as floods and droughts. The impacts are already being felt and the poor in the developing countries, who have the least capacity to cope with these impacts, are the ones most at risk through climate change. Marginalized population groups, but also decision makers on government levels, are often lacking knowledge and expertise to understand and adapt to climate change. Creating awareness about present and future changes and building capacities for adaptation at all levels of society is an integral part of successful adaptation to climate change. Climate education comprises all measures that aim to prepare people to cope with the risks climate change provides for different regions.

Education measures are adjusted to the respective local and social conditions of the audience. Therefore, a variety of participatory, interactive methods exists for climate education:

- Action plans for schools and communities
- Guided tours within the community, led by local adaptation experts to demonstrate what the municipal or individuals already have done to adapt to climate change. On the basis of practical examples, people learn about the possible and actual measures for adaptation.
- Development of "climate-safety-codes" in schools (publicly displayed do's and don'ts that communicate adaptation messages, e.g. "don't throw garbage into the rivers!", "Don´t spill medicine and other chemicals into the water!").
- Trainings and workshops that are tailor-made for the respective audience, information and location by selecting adequate presentation methods from the various media available.

Media for climate education

- Television, Radio
- Audio media
- Video, Podcast
- Audio-visual methods (slides, flipcharts, fotostories, wallpapers)
- Printed materials (books, brochures, comics, magazines, newspapers, manuals, handouts, flyers)
- Posters
- Traditional media (theater, drama, songs, puppetry, story telling, games, etc.)

(List from Oepen, Hamacher, 2000)

The podcasting technology is an innovative method that can be applied where few trainers are available, no electricity and telephone infrastructure exists and most of the areas are inaccessible. The technology has been successfully applied in Mbire, Zimbabwe (see also case study next page).
After three months of content development, information was recorded (and regularly updated) on MP3 players. Trainers can use the podcasts to provide information about diverse disciplines, including disciplines in which they may not be experts.

Issues to Consider

- make tools and material available in the respective languages of users to ensure that local experts are able to fully participate in the adaptation process
- cooperate with local partners to sustainably establish adaptation knowledge, find qualified and interested training institutions
- establish and strengthen centres of excellence, such as universities and research institutions
- use interactive and participatory methods
- promote indigenous knowledge (for adaptation) and thereby encourage local ownership
- find local, realistic and affordable solutions for adaptation (capacity of poor households to use established adaptation strategies is limited)
- integrate local topics (photos, comments of local fishers or farmers) and find (local) role models
- instil climate change awareness and understanding at a young age to change behaviours and attitudes

Advantages

- participatory approaches enhance identification and local ownership
- self-sufficiency of people affected by climate change increases
- knowledge about climate change spreads within communities (disseminator effect)
- awareness-raising enhances acceptance and facilitates implementation of adaptation measures, people may better identify their needs

Challenges

- gain sustainability within a relatively short time frame
- build capacities of local actors to continue providing locally relevant information
- address/understand local needs and cultural background
- find and teach adaptation strategies that are applicable for poor households
- adapt to limited capacity of poor households to use established adaptation strategies
- podcasting: questions of the audience may remain unanswered when trainers are not experts

Case Study: ***Coping with Drought and Climate Change*** **in Zimbabwe**

The project is implemented by UNDP and the Environmental Management Agency (EMA) of Zimbabwe. The semi-arid Chiredzi District, located in the South East of Zimbabwe, serves as pilot area.
Stakeholders involved into the project include local farmers, development practitioners, government, researchers, as well as international partners and donors. Within the project, a seasonal climate forecast system for Chiredzi district has been developed. Farmers contribute to the system by monitoring rainfall with rain-gauges and by providing indigenous knowledge. For example, the occurrence of certain bird species is traditionally used for long-term rainfall predictions and south-easterly winds give farmers the confidence that it will rain within the next week.
Demonstration projects have been implemented across vulnerability "hot-spots" of the district, enabling farmers to use climate information to adapt to changing weather conditions. Government officials and NGOs are being trained on the use of climate and drought information on institutional levels.

For more information, see http://www.ema-cwd.co.zw/

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