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GLOWA Jordan River Project
Integrated research for sustainable water management

Abstract

The Jordan region is facing severe and increasing water scarcity. Solutions to the emerging water crisis are still very fragmented and subject to the political situation.
The GLOWA Jordan River project provides scientific support for integrated water resources management. A key component of the project is the integration of water and land management, using the so-called "blue-green water concept" which integrates surface and groundwater fluxes with evapotranspiration from vegetation. Based on climate and other scenarios, that are developed jointly with stakeholders, different adaptation options are tested for their eco-hydrological impacts and costs and benefits, using the full range of scientific tools from experiments, monitoring, simulation models to socio-economic surveys and assessments. Eventually information from the GLOWA project is integrated with other regional knowledge in a central decision support tool.

Introduction

Global change and globalization pose additional threats to save water supply in addition to increasing local pressures in many regions of the world. Common expressions of the looming water crisis are decreasing water availability, pollution and increasing demand, as well as higher climate variability and more extreme events (see e.g. WWDR 2003). Given the key role that water plays for humans and ecosystems, effects of water scarcity include hunger, disease, poverty, and ecosystem degradation. The complex interactions of local regional and global pressures on water resources and feedbacks of water scarcity on other sectors are best addressed in the framework of integrated water resources management (IWRM, see GWP 2000).

Sustainable water management requires a combination of complementary technical, economic, social and political measures, adapted to the respective local contexts (GWP 2000). The German Ministry for Education and Research (BMBF) is responding to this challenge with a concerted research effort in support of sustainable water management, the GLOWA programme. This programme has been implemented in a transect of five integrated regional projects in Europe (Elbe, Danube), Middle East (Jordan River) and Africa (Volta, Draa / Oueme). These projects develop, jointly with stakeholders, integrated strategies for water management under global change, adapted to the regional socio-economic and ecological conditions. Here, we present the approach and concept of the GLOWA Jordan River Project.

The Water Situation in the Jordan River Region

Like in many semi-arid regions, high spatial and temporal climate variability pose severe challenges to water management, e.g. pronounced dry seasons, high inter-annual variability in precipitation and steep gradients of water availability away from the coast and from the highlands.

Water scarcity in the Middle East is among the highest in the world. Groundwater and surface water resources are fully committed and sometimes overexploited. For example, per-capita water availability in Israel is currently at 265 m^3 per year and in Jordan at 170 m^3 (WRI 2004), which is below all thresholds of water scarcity (e.g. 1700 m^3 or 1000 m^3 per capita and year, Falkenmark 1999).

Regional water scarcity is expected to increase further, due to internal and external pressure, in particular:

- decreasing water availability, due to climate change effects, such as increasing temperatures and higher climate variability (Alcamo 2003, Arnell 2004);
- increasing water demand, given that population growth rates are among the highest in the world (WRI 2004)

Conflicts over water are triggered also by unequal distribution of water resources in the region. This inequity is partially due to natural and climatological factors, but also to the political and economic situation. Consequently, water use conflicts often have a political component or political implications (Allan 2003, Jägerskog 2001). Sustainable solutions to the pressing water crisis are difficult to achieve under the current political situation. However, progress in resolving water issues can also facilitate the overall peace process. The special role of the water sector is also evident from the continuous activities of the Palestinian-Israeli Joint Water Committee and the agreement of both parties to keep water infrastructure intact, despite the conflict.

Adaptation to water scarcity and high climate variability has a long tradition in the region, which has been termed “cradle of agriculture” (Issar 2004). Water harvesting and irrigation have been applied for many centuries of even millennia, drought resistant crops have been used, and water productivity in irrigated agriculture has increased several times in recent decades (Tal 2004). The region is leading in technologies such as drip irrigation, green houses, wastewater reuse and more recently also seawater desalination.
For example, Israel strongly promotes the development of non-conventional water resources or „manufactured water“, in particular the reuse of wastewater and desalination, to overcome water scarcity. By the end of this decade, reuse of wastewater is expected to exceed the use of freshwater in agriculture. In parallel a number of desalination plants will be operated along the Mediterranean coast with a total capacity of about 500 million m^3 per year (Water Commission 2003).
Jordan is rethinking a Red Sea – Dead Sea canal to increase water supply, in addition to demand management measures (El-Naser 2004). In this canal, the difference in elevation (sea level to 400 m below sea level) could be used to desalinate the water.

Despite all measures taken so far, the region “has run out of water” in the 1970s and can not be food self sufficient any more (Allan 2001). Adapting to this water scarcity, the region has more than any other region replaced local food production with food imports. The food demand of Israel and Jordan is mostly met through annual food imports, that require 2-3 times more water for their production than the total renewable resources of these two countries (Chapagain & Hoekstra 2004).

Despite the large number of strategies, plans and projects, supported by regional governments and also by development cooperation, the water crisis is far from being solved. Therefore, within the integrated water resource management (IWRM) concept, water research needs to consolidate and improve the knowledge base, in particular to provide a better understanding of the complex interactions between natural processes and human resource use. Interdisciplinary and integrated projects are required to foster the application of scientific knowledge for maximizing the joint benefit of scarce water resources.
To this end, social, economic and environmental costs and benefits of different adaptation options need to be assessed simultaneously. Traditional disciplinary research approaches cannot provide the required comprehensive assessment of pressures, impacts and responses,

because they focus on single aspects of water availability, demand or quality. The GLOWA Jordan River Project addresses this gap between science and application in water management.

The GLOWA Jordan River Project

The German Ministry for Education and Research (BMBF) has initiated the GLOWA (Global Change and the Hydrological Cycle www.glowa.org) programme, as an integrative science approach towards sustainable management of larger river basins (Rieland 2004).

In the youngest of the five GLOWA projects, GLOWA Jordan River (www.glowa-jordan-river.de), Israeli, Jordanian, Palestinian and German scientists jointly analyze the regional water crisis and possible solutions under current and global change conditions, in a set of complementary activities.

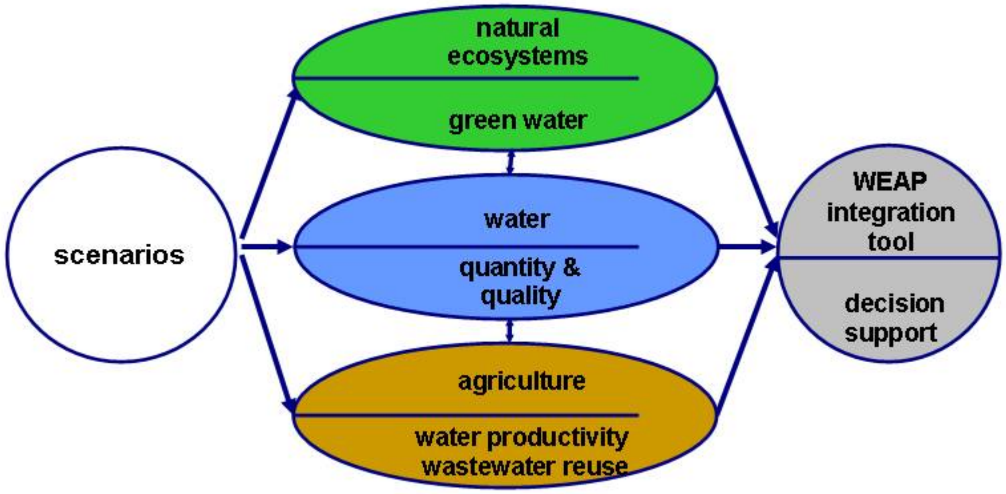
The first phase of this project (until mid 2005) has provided better process understanding and described the current situation, in particular the interactions and feedbacks of different aspects of regional water availability, demand and quality. Key trends of global change and globalization and their effects on regional water resources have been identified (e.g. Alpert 2004, Shaheen et al 2005). The system understanding gained in phase 1, provides a basis for the second phase of the project (2005-2008), in which scenario-based management options will be developed and assessed.
Close collaboration with different partners and stakeholders from water management, politics, development cooperation and NGOs helps to bridge towards application.

The GLOWA JR project has five work-packages (Fig. 1). Through coupling of all work-packages and integration of results in a central decision support tool, all components contribute to the central goal, i.e. scientific support for sustainable management of regional water resources. The five work-packages are:

1. Global Change Scenarios
2. Water Resources, Availability, Demand and Quality
3. Water in Natural Ecosystems
4. Water in Agriculture
5. Integration and Application

In the following, we briefly outline the main approaches and results of these workpackages.

Fig 1: Integration scheme for work-packages 1-5 in the GLOWA Jordan River Project



Global Change Scenarios

All work-packages of GLOWA JR are scenario-based. The first phase has focused on the development of regional climate scenarios as a basis for all other activities. These high-resolution scenarios are driven by global climate models, employing statistical and dynamical downscaling methods (Kunstmann 2003, Boehm et al 2004). By coupling these scenarios with hydrological models, future water availabilities are calculated. These key drivers enter all other work-packages and projects.

Besides improved regional climate scenarios, phase 2 will also develop additional scenarios, in particular socio-economic scenarios. Initially, these will be qualitative scenarios or “storylines”, developed iteratively between stakeholders and scientists. The stakeholders identify plausible future trends and key decisions in water management, and GLOWA science validates, refines and quantifies the initial storylines, employing experiments, monitoring and simulation models. Relevant scenarios in GLOWA JR may address land use, agricultural subsidies, investments and new technologies, but also international trade or life-styles. Relevant land use trends include changes in agricultural areas, including irrigated and grazing land, as well as protected areas and urban areas and their respective effects on hydrology and water resources.

Water Resources, Availability, Demand and Quality

In the first phase of GLOWA JR, water and constituent fluxes have been quantified for selected sub-catchments in the upper Jordan River and in the lower Jordan River, i.e. in side-wadis east and west of the lower Jordan River. Existing data on surface and groundwater resources have been compiled (e.g. Litaor et al 2004)

The second phase will build upon these achievements and results from other initiatives, by consolidating information in a central decision support (WEAP, Water Evaluation and Planning) tool and GIS data base.

When consolidating hydrological data, so-called “green” water fluxes (evapotranspiration from soils and plants will be integrated with “blue” (surface and ground) water fluxes (Falkenmark and Rockström 2004) for a full balance of all available water and the respective uses, including water fluxes in natural ecosystems, rainfed agriculture and grazing land. Green water provides the central link between water and land management. By taking into account green water fluxes, new scenarios of integrated land use and water use by humans and ecosystems will be developed.

Horizontal and vertical water fluxes are coupled and regionalized in GLOWA JR to the full basin scale. From that, spatial and temporal variability of water availability can be derived for the upper and lower Jordan River catchments for specified regional climate scenarios. Subsequently, the ecological and socio-economic implications of different management options for natural ecosystems and rainfed and irrigated agriculture will be assessed.

Water in Natural Ecosystems

The GLOWA JR project area comprises four biogeographic regions (Shmida & Aaronson 1986). The climatological boundaries of these biogeographic regions are largely determined by availability and temporal dynamics of precipitation. Hence natural ecosystems are likely very vulnerable to climate change. Vulnerability of natural ecosystems is a focus of GLOWA JR. GLOWA JR integrates bioclimatic models with mechanistic ecological and hydrological models, and analyses feedbacks between climate, land use changes, flora and fauna. Subsequently, socio-economic consequences of ecosystem changes are analyzed by assessing and changes in ecosystem services and by using e.g. willingness-to-pay approaches.

During the first phase of GLOWA JR, the effects of climate change (in particular changes of precipitation) on structure and composition of different ecosystems have been analyzed along a steep regional precipitation gradient (e.g., Holzapfel et al. in press, Petrů et al. in press). Manipulative experiments, in particular rain-exclusion and artificial rain experiments, are complemented by spatially explicit vegetation models (Jeltsch & Moloney 2002), follow a space-for-time approach, which uses the spatial gradient as a substitute for long-term climate changes (Dunne et a.l 2002).

From the water resources perspective, natural ecosystems compete with rainfed agriculture or grazing for scarce (green) water. Hydrological effects of different land management options (protection, grazing, afforestation etc.) will be regionalized in phase 2, e.g. with respect to water consumption, runoff generation or groundwater recharge.
Integration with the agricultural work-package of GLOWA JR is achieved through coupled ecological and hydrological experiments and modeling, as well as socio-economic and ecological cost-benefit assessments of different management options. The goal is to maximize the overall benefit derived from the scarce green and blue water resources.

Water in Agriculture

Agriculture consumes the majority of all water in the Jordan basin, i.e. about two thirds of all (blue) water resources (GTZ 1998) and even larger volumes of green water. At the same time, agriculture and irrigation are the cause of considerable loads of salts, nutrients and pesticides in surface and groundwater. In phase 1 of GLOWA JR, nutrient transport in agricultural drained land have been analyzed and the fate of organic substances from reused wastewater and of steroid hormones has been monitored (e.g. Shore et al 2004).

The second phase will assess different agricultural management options under a range of global change scenarios, in order to minimize adverse impacts for humans and nature, and to maximize the overall benefit of scarce water resources.
One focus will be on reuse of wastewater for agricultural irrigation, integrating treatment level, resulting water quality, vulnerability of receiving soils and groundwater to contamination, and costs and benefits for farmers, consumers and environment.
Another focus will be on green and blue water productivity in irrigated and rainfed agriculture.

Given the expected reallocations of blue water from agriculture to urban and other water users (Taha et al 2004, Tal 2004), a combination of adaptation options will be required, in order to ensure food security. This will include on one hand increases of water availability, use of non-conventional water (Tal 2004), i.e. reused wastewater, desalinated water and harvested rainwater, but also increases in water productivity, i.e. biomass production per liter of water used (Oweis 2003), and further substitution of local food production through virtual water imports, i.e. imports of food (Allan 2003).

Integration

By integrating results from the above work-packages, GLOWA JR will improve the understanding of global change effects and tradeoffs between different adaptation options, when trying to maximize benefits for humans and nature through integrated water resource management.

Scientific integration and bridging to water management is facilitated by

a) joint development of scenarios with scientists and stakeholders (SAS approach, Alcamo 2001), and
b) cost-benefit analyses of various water and land management options (e.g. optimization of water allocations, reuse of wastewater, land use planning, substitution of agricultural production with food imports, and
c) synthesis of results in a geographically explicit decision support tool (WEAP). This allows water managers and other users to simulate the hydrological and economic consequences of different global change and management scenarios (Yates et al 2005).

Conclusions

Given the pressing and ever increasing water scarcity in the region, a portfolio of adaptation measures is required to ensure water security for humans and sustainability of ecosystems. Besides the standard measures of increasing supply – e.g. through desalination and wastewater reuse - and managing water demand in agriculture and municipal systems, major potential for improvement lies in the integration of blue and green water use.
The GLOWA JR project supports this concept through well coordinated experiments, model simulations and cost-benefit assessments, in a collaboration of Jordanian, Palestinian, Israeli and German scientists from a wide range of socio-economic and biophysical disciplines.
All of these GLOWA activities are based on a set of realistic, quantitative scenarios, which are developed jointly between GLOWA scientists and stakeholders. The resulting scenario-based information will be synthesized for application in water management in a central decision support tool (WEAP). With that, GLOWA JR helps to operationalize the principles of Integrated Water Resources Management in the region, and supports cooperation over shared water resources.

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