10 Challenges in upland watershed management

The green-blue water approach

Holger Hoff

Increasing water scarcity requires a widened integrated water resources management (IWRM) approach, which includes green water as an additional resource to be managed. Best practices and cross-sectoral adaptation, according to the new green-blue water approach, provide new degrees of freedom by increasing water productivity and enhancing water-related ecosystem services for higher overall benefits, compared to conventional infrastructure and blue water solutions. Payments for environmental services (PES) can reconcile upland poverty alleviation with improved downstream water availability, and bridge the gap between field-scale soil and water conservation and basin-scale IWRM. Applying green-blue water principles to clean development mechanism (CDM) afforestations can increase their sustainability and generate additional funding for IWRM activities.

10.1 Introduction

Water stress in many parts of the world is increasing in terms of water quantity as well as quality. Humans are at the same time causing this water stress and suffering from it. Human appropriation of surface and ground water, changes in land use, release of pollutants, and other direct and indirect pressures are all contributing to the growing water crisis. Degradation of water resources and lack of access to safe water threaten human well-being and are closely linked to food insecurity and poverty in many parts of the world. The Millenium Development Goals cannot be achieved without improving water management significantly (Soussan and Noel 2005, Rockström *et al.* 2005). Also, aquatic and terrestrial ecosystems and their services critically depend on availability of sufficient amounts of water and the appropriate temporal distribution.

Global and regional assessments are projecting an increasing number of people, ecosystems, and basins subject to water scarcity (Rockström *et al.* 2007, Smakthin *et al.* 2004, Vörösmarty *et al.* 2000). Many basins have come close to, or have even reached, the state of a "closed basin," in which all available surface and ground water is committed and any re-allocations or improvements for one group or in one part of the basin would come at a cost of another. Under such conditions, any increases in upstream water use, e.g. from agricultural intensification, would cause downstream shortfalls in water supply.

In response to these mounting pressures, IWRM has been introduced as a useful framework, primarily to address solutions at catchment to river basin scale. According to what is probably the most widely used IWRM definition by GWP (2000), IWRM is "a process, which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." Despite the good intentions of this definition, coordinated water and land management is not yet practiced in most river basins around the world. The key role of land management in alleviating water scarcity is hardly recognized.

This chapter demonstrates through some examples the important links between upstream land use and downstream effects on water resources, and attempts to identify successful institutional adaptations that address these upstream-downstream links for improved water availability, productivity and allocation equity. While upland management also can have strong impacts on downstream water quality, this chapter is limited to water quantity effects.

10.2 Upstream–downstream links: the green-blue water approach

Generally, assessments of water scarcity, as well as implementations of the IWRM concept, are limited to the so-called "blue water" and fail to recognize that most of the water in the hydrological cycle that supports humans and ecosystems is, in fact, "green water."

10.2.1 Green and blue water

The concept of green water is not new. Only recently, however, possibly in response to the growing water crisis in many parts of the world, has this concept received the attention it is due. Blue water is water in rivers, lakes and ground water, for use in irrigation and municipal and industrial water supply. It also sustains aquatic ecosystems. Green water is the water infiltrated into the soil from precipitation. It provides a large natural storage of water, similar to ground water but accessible to natural and agricultural vegetation only. This green water storage by far exceeds that of man-made reservoirs in magnitude. Human appropriation of green water is almost an order of magnitude bigger than the appropriation of blue water. Green water storage and the green water fluxes between soil, vegetation and the atmosphere depend largely on land cover and management. Effective land management can improve the productivity of green water (mostly by reducing unproductive losses), which can contribute significantly to alleviating water scarcity for cases in which renewable blue water is already fully exploited.

Recognition of green water as a resource to be managed within the IWRM framework opens new degrees of freedom in so-called drylands, many of which are not all that dry, given their relatively high annual precipitation which can be managed better.

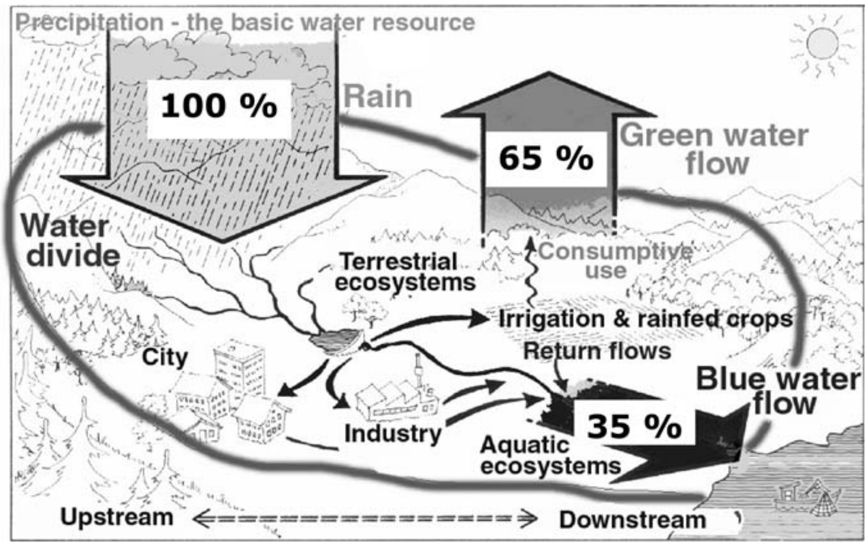

Figure 10.1 Partitioning of precipitation into blue water (surface runoff and groundwater recharge) and green (soil) water (Falkenmark 2003). (Source: Falkenmark and Rockström 2004).

Neglecting green water fluxes and their role in sustaining ecosystems and human livelihoods gives an incomplete view of the water situation in most regions of the world. In Africa, for example, more than 95 percent of agriculture is rainfed. The fluxes of green water that support agriculture and other terrestrial ecosystems and their services are generally not taken into account in IWRM planning in most countries and basins. Consequently, even in the driest places, under most pressing water scarcity, land use is generally not considered part of IWRM.

At the global scale, humans have significantly altered the partitioning of precipitation into green and blue water by changing land use. Initial assessments indicate that, cumulatively, deforestation and transformation into agricultural land have increased global discharge by about 1,700 km^3/yr, or by five percent, compared to the discharge from natural vegetation cover (Rost *et al.* 2007). In order to understand the magnitude of these anthropogenic changes, it is worthwhile comparing them to the total global blue water consumption for all municipal and industrial uses, which amounts to about 100 km^3/yr (Rost *et al.* 2007).

At local to regional scale, upland deforestation can significantly increase downstream water availability, often reducing evapotranspiration by 100 mm/yr or more (Gerten *et al.* 2005). The opposite is true for afforestation. In particular, larger afforestation schemes, such as the billion-tree campaign by the World Agroforestry Centre and the United Nations Environment Program (ICRAF/UNEP)[1] and also afforestations as part of the CDM or for biofuel production have to be evaluated for their hydrological consequences within the IWRM context.

The higher water losses to the atmosphere of forests compared to those of other vegetation types are explained by the fact that trees have:

1 higher leaf area indices, hence higher canopy interception losses and transpiration potentials, as well as higher surface roughness (thus greater evaporative losses);
2 deeper roots, which can tap additional layers of soil moisture; and
3 no fallow period as for agricultural vegetation (at least for evergreen trees that do not defoliate) during which transpiration is strongly reduced.

Despite these straightforward physical explanations backed up by experimental evidence of enhanced tree water use (Calder 2005), there is still a widespread misconception that afforestation would increase water availability (forests holding water in the landscape), upon which many watershed programs around the world have been built (Hayward 2005).

Besides changes in forest cover, a number of other upland changes generally affect downstream water availability. Upland irrigation water withdrawals from surface water reduces downstream runoff. Also, soil and water conservation measures often increase plant water uptake, reduce runoff, and contribute to lower flows downstream.

The green-blue water approach, which emphasizes precipitation as the key water resource to be managed, rather than blue water only, promotes a better understanding of land-water interactions and improved upland management, based on scientific evidence, rather than popular beliefs. A key component of this approach is the reduction of unproductive water fluxes (mostly evaporation) and associated increase in water productivity (mostly through enhancing beneficial transpiration), aiming at improved ecosystem services and multiple benefits for upstream and downstream water users.

There are numerous individual measures that can support these goals, summarized in the World Overview of Conservation Approaches and Technologies (WOCAT) database[2], including appropriately designed water harvesting and storage, supplementary irrigation, and conservation agriculture. Most of these interventions have been tested individually at field scale for their beneficial effects, in particular reduced runoff, more deep drainage, and less erosion and sediment yield, in various land and water conservation programs especially in Africa, such as the Regional Land Management Unit (RELMA)[3], the Smallholder System Innovations in Integrated Watershed Management (SSI)[4] and others.

However, the cumulative effects of upland interventions on downstream water availability have not been quantified systematically. The identification of these effects is difficult, because of the complex interplay of abiotic and biotic factors that determine water flows along the river course. Also, hydrological responses to these interventions, such as improved groundwater recharge or reduced siltation may be delayed in time. Upscaling from plot-scale experiments to the catchment and river basin requires integration over the cumulative primary and higher-order effects (Kabat *et al.* 2004). Separation of these effects from (increasing) climate variability may further complicate the analysis.

While there is no conclusive evidence, let alone guidelines on the overall effects of upland management on downstream water availability, initial applications of the key principles of integrated land and (green and blue) water management are found in various regions around the world, including the United States, South Africa, India, as well as in eastern Africa and the Middle East (see examples below).

The New York City Watershed agreement demonstrates how upland farmers – if paid for improved land management – can ensure good water quality downstream. New York City has agreed to provide $35 million for farmers in the upstream Catskills catchment to install pollution abatement devices, e.g. fencing to improve cattle feeding or riverside tree planting. Upstream benefits of this well-known scheme include increased farmers' incomes and higher farm productivity in nine out of 10 cases. Downstream benefits include the avoided costs of some $6 billion for a new water filtration system (CCCD 1997). From a basin-wide perspective, the protection of the upper watershed (at the source) is much more cost effective than downstream (end-of-pipe) rehabilitation measures.

The South African water legislation is another prominent example of applying the green-blue water principles (although not under this name). South Africa's National Water Act requires farmers to apply for permits before initiating so-called "streamflow reduction activities," in particular forest plantations (DWAF 1999). This "user-pays principle" has established a kind of water tax for owners of upland commercial tree plantations.

A related assessment of the different land uses in South Africa in regard to their water requirements concluded that all commercial tree plantations together reduce the nation's surface runoff by 1.4 billion m^3 per year, or 3.2 percent of total flows. Following the example of forest plantations, a designation of sugar cane plantations as streamflow reduction activities is now also under discussion in South Africa. While the legislative framework for integrated (green and blue) water and land management has been developed in South Africa, it is not yet clear to what degree it is now enforced through appropriate institutions.

These examples, as well as those of the Jordan and Tana Rivers described in subsequent sections of this chapter, indicate that integration of upstream land management into catchment-wide IWRM planning and accounting for all green and blue water uses, can increase overall productivity and benefits derived from limited water resources, while at the same time reducing costs, e.g. for maintaining water quality and ensuring sufficient water supply for humans and ecosystems. Economic incentives for adopting green-blue water principles and associated soil and water conservation techniques for promoting sustainable catchment management and eventually also for more equitable allocations of water between all users, will be described in the section of this chapter on payments for environmental services (PES). In order to move from scientifically established green-blue water principles to application, making land management integral part of IWRM, requires capacity building on many fronts and new cross-sectoral cooperation, e.g. between different ministries, water and land authorities and other institutions that are not commonly cooperating.

The new Green-Blue Water Initiative (Falkenmark and Rockström 2005) will establish pilot studies in several basins around the world, in order to demonstrate and promote the concept of integrated water and land management across scales, from a local, catchment, basin, national, and regional level up to the global scale. This concept is now receiving much attention, also under the impression of the latest climate change projections for increasing variability and water scarcity, and the need to increase resilience in many parts of the world.

10.3 Climate change impacts and adaptation

According to the Intergovernmental Panel on Climate Change (IPCC 2007), climate change is projected to add pressure to many water-scarce regions, resulting from increasing temperatures and evaporative demands, changing rainfall volumes and distribution, and increasing intra- and inter-annual variability and uncertainty in water management. With pressures from population and economic trends, these factors will increase the vulnerability of people and ecosystems to the vagaries of climate.

Upstream-downstream relationships also will be affected by climate change through hydrological and vegetation responses. Non-linear responses, even to relatively small temperature and precipitation changes, may produce large changes in runoff or groundwater recharge. De Wit and Stankiewicz (2006) showed that precipitation reductions of about 10 percent, as projected for parts of Africa over the twenty-first century, may translate into reductions in drainage of up to 50 percent and more. Döll and Flörke (2005) project reductions in ground water recharge of more than 70 percent by 2050 in parts of Africa and the southern Mediterranean for different emission scenarios.

The benefits of robust adaptation strategies to climate risks go beyond mitigating water scarcity: adaptive management of water and land can reduce vulnerability to other pressures and also mitigate upstream-downstream conflicts. In the case of transboundary basins, cooperative water management may foster political collaboration in other sectors, as in the Jordan River basin (see Jordan section of this chapter).

An integrated approach to water and land management also can support the coordination of climate change mitigation and adaptation. Environmental sustainability criteria for CDM-related afforestation projects, for example, should include impacts on hydrology and water resources. These need to be assessed also with respect to adaptive management under climate change. Benefits of afforestations in terms of carbon sequestration (or biofuel production) have to be balanced against downstream "water costs," particularly if there is competition for water for food production or other ecosystem services (see Tana section of this chapter).

In some regions, global warming will cause additional upstream-downstream effects from melting glaciers: the water draining from the Himalayan glaciers, for example, ensures continuous water supply in the dry-season to hundreds of millions of people living in the Indo-Gangetic plains. As much as 70 percent of the Ganges summer flow originates from these glaciers (Barnett *et al.* 2005; see also Messerli in this volume). Melting of glaciers has already accelerated and, as a result of further warming, the Ganges runoff may increase by 30 to 40 percent over the coming decades, with more flooding projected for northern India and Pakistan. In the long run (after about 40 years), however, most glaciers will have disappeared and, subsequently, Indus and Ganges runoff is projected to decrease by more than 50 percent compared to the current situation, with severe consequences for water availability, food production, and livelihoods (Hasnain 2004). Similar downstream effects are expected or already observed for many mountain regions around the world. In this case, the responsibility is not with upland managers, but with greenhouse gas emitters around the world, who are ultimately responsible for melting glaciers in the headwaters and subsequent downstream water scarcity. Application of a "polluter-pays" principle would require compensation from major emitters to those being affected most. This could be in the form of adaptation funding from multilateral or bilateral donors.

The following two sections will focus on more direct upstream-downstream links in the Jordan and Tana Rivers, and the potential for institutional adaptation in view of the increasing scientific knowledge that supports integrated (green and blue) water and land management.

10.4 Jordan River basin management: addressing upstream-downstream links

The Jordan River is characterized by a strong climate gradient from its headwaters that receive more than 1000mm of precipitation per year, to the downstream section with less than 100mm/year. Most runoff is generated in the upper Jordan (and Yarmuk) basin(s), while water use primarily takes place in the lower part or outside of the basin via large-scale water transfers (see also the chapter by Rimmer in this volume). Hence, contributions to and withdrawals from the Jordan River have very different national distributions, which is (among others) a cause for conflict between the different riparians, as shown in Table 10.1.

The strong degradation of the lower Jordan River, and the rapidly declining

Table 10.1 Contributions to Jordan River runoff and withdrawals from the basin (incl. groundwater)

	Contributions (million m^3/yr)	*Withdrawals (million m^3/yr)*
Jordan	530	320
Syria	435	260
Israel	160	<700
Palestinian Authority	155	60
Lebanon	120	10

Source: Phillips 2006a, b.

level of the Dead Sea – about one meter per year – are primarily caused by the enormous water withdrawals in the upper Jordan River, in particular the diversions through the National Water Carrier in Israel and King Abdullah Canal in Jordan, which together with other withdrawals reduce the Jordan River flow by more than 75 percent. Some of the ground water resources that extend beyond national boundaries also are overexploited. The transboundary nature of surface and ground water and the associated shared responsibility for the resource, seems to increase the risk of overexploitation.

Climate change is projected to aggravate this situation. Most global climate models agree on a decrease of precipitation in the eastern Mediterranean over the coming decades (IPCC 2007), in addition to the global trend towards higher temperatures and increasing climate variability. According to these projections, climate impacts will include:

- decreasing runoff, ground water recharge and water availability
- increasing water demand for irrigated and non-irrigated agriculture and other vegetation
- increasing frequency/intensity of droughts, and associated uncertainty in water management.

The GLOWA Jordan River project[5] assesses eco-hydrological and agro-economic impacts of climate change projections and has developed tools for evaluating different adaptation options and tradeoffs between them (Hoff *et al.* 2006a). Initial impact studies, based on downscaled regional climate scenarios, indicate severe reductions of surface and groundwater availability for all months, accompanied by strong increases in irrigation water demand – Figure 10.2a (Kunstmann *et al.* 2007) and Figure 10.2b (Menzel *et al.* 2007), and subsequent losses in yields and net returns on investment in agriculture – Figure 10.2c (Haim *et al.* 2008).

These climate-related pressures may intensify upstream-downstream imbalances and aggravate water-related conflicts, unless climate variability and change can be built into agreements on integrated and transboundary management of water resources. Unfortunately, the current political situation in the upper Jordan does not allow for any basin-wide agreements. Existing bi-lateral watersharing arrangements between Syria and Jordan, as well as between Jordan and Israel, are already disputed or are prone to fail in drought years.

Instead of developing sustainable upstream-downstream agreements including demand management, a new water transfer project is now planned in the lower Jordan. It is much larger than any previous infrastructure project: a conduit between the Red Sea and the Dead Sea, which could produce large amounts of desalinized water, utilizing the elevation gradient between the two seas. While this multi-billion-dollar project could also reverse the decline of the Dead Sea, the root causes of the problems that lie in the upper Jordan would not be addressed through such a conduit. Instead, this mega project would allow continued (unilateral) overexploitations of upstream resources, without any provisions for restoring the lower Jordan River.

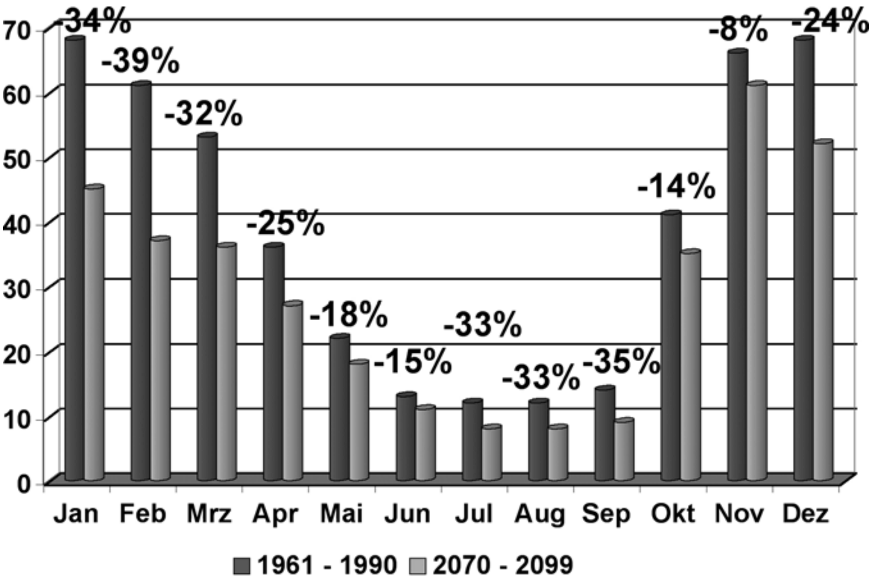

Figure 10.2a GLOWA scenario of changes in Jordan River discharge (ECHAM4 global climate model, B2 scenario, MM5 regional climate model, WASIM hydrological model).

The Jordan basin is generally viewed as a so-called closed basin with fully exploited surface and ground water (blue water) resources. Politically, this is interpreted as a situation in which any re-allocations of water come with expensive tradeoffs, and the only significant improvement would require expensive schemes for generating "new water," such as the Red Dead Conduit, or other desalination or other high-tech infrastructure projects.

In this situation, the green-blue water concept can provide a way forward, re-opening the basin, by identifying additional (green) water resources/soil water storage to be managed. Integrated land and water management offers a number of interventions, including small-scale affordable measures and win-win options within and between the riparian countries.

Currently unused potential for increasing water availability and productivity results mainly from the fact that 80 to 90 percent of rainfall in the drier parts of the basin neither becomes blue water, i.e., surface or ground water, which could be subject to water management, nor contributes to biomass production. Instead, most of the rainfall is lost uncontrolled and unproductively through evaporation. If only a fraction of this lost water were to be captured, e.g. through rainwater harvesting, water availability could be augmented significantly. Simple low-cost harvesting technologies, such as those tested successfully in the Negev and Badia drylands (i.e. adjacent to the Jordan basin) could become even more beneficial under climate change, when rainfall events are projected to become more sporadic but more intense with higher storm runoff losses.

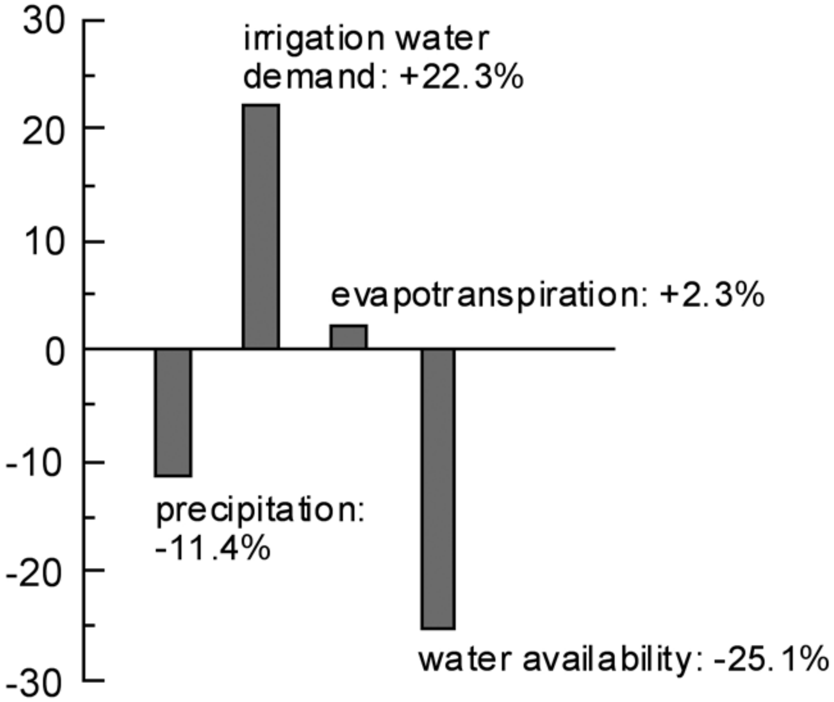

Figure 10.2b GLOWA scenario of changes in the different hydrological components in the Jordan River basin (ECHAM4 global climate model, B2 scenario, MM5 regional climate model, TRAIN hydrological model).

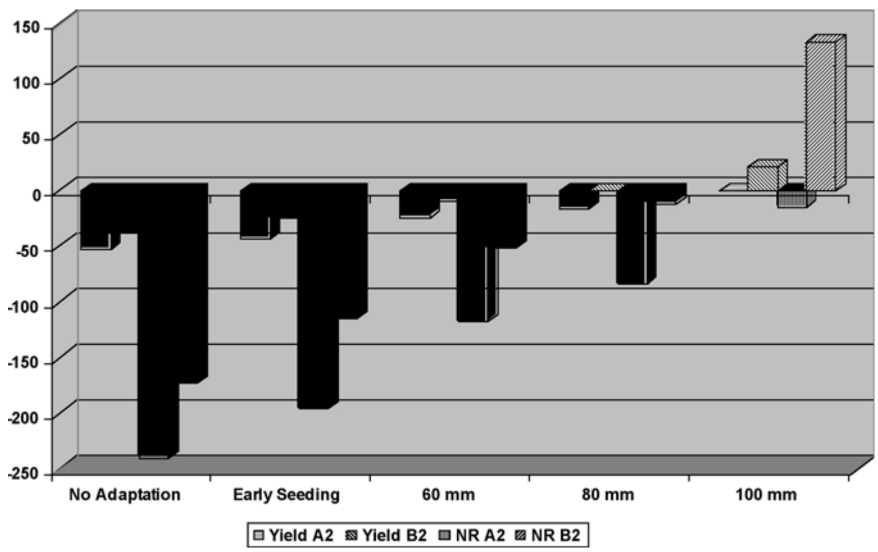

Figure 10.2c GLOWA scenario of changes in yield and net return for cotton for different climate scenarios and adaptation options.

Another missed opportunity lies in agricultural practices in the Jordan region, which are generally assumed to depend primarily on blue water, i.e., irrigation. However, initial analyses by Haddadin (2006), indicate that at least half of the water supporting agriculture in the region is green water, either in rainfed agriculture or precipitation entering irrigated systems – plus much larger amounts of green water supporting grazing land. Improved co-management of green and blue water in agriculture, e.g. through rainwater harvesting, supplementary irrigation and conservation agriculture, can increase overall water productivity significantly by shifting water fluxes from unproductive evaporation to productive transpiration (Oweis and Hachum 2004) – see Figure 10.3. With that, pressure on blue water exploitation can be reduced, with positive effects on downstream water availability. Appropriate interventions, which improve green and blue water productivity, depend on the level of technologies available, which varies significantly across the Jordan River basin. Many green water management measures are affordable for the rural poor, so they can benefit directly from improved income and resilience to climate and other pressures – different from most large-scale blue water schemes, which do not necessarily yield direct benefits for the poor.

Further potential for improved land and water management is related to the rapid urban sprawl in the region, with urbanization often taking place on highly

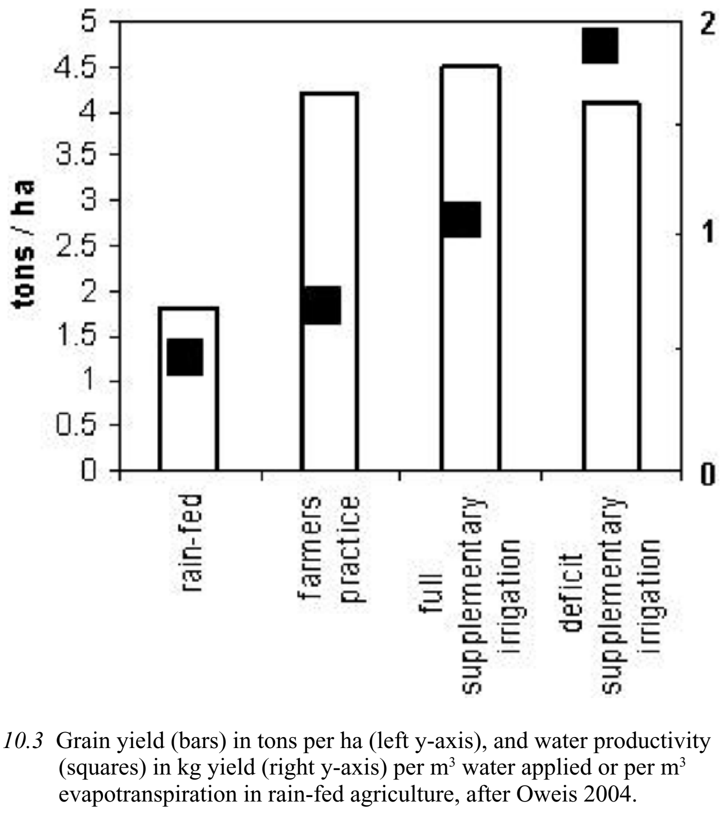

Figure 10.3 Grain yield (bars) in tons per ha (left y-axis), and water productivity (squares) in kg yield (right y-axis) per m^3 water applied or per m^3 evapotranspiration in rain-fed agriculture, after Oweis 2004.

productive agricultural land. Initial assessments of changes in blue and green water fluxes due to urbanization and associated surface sealing and losses of soil water storage, indicate that optimized land use and urban planning as part of IWRM could increase green and blue water productivity significantly.

Given the large gradients in climate, water availability (ranging from less than 100 m^3 per capita and year in the Palestinian Authority to more than 1,300 m^3 in Syria (WRI 2007), technological capacity and water productivity across the basin, cooperative upstream-downstream allocations and management of green and blue water and land hold enormous potential for improving overall productivity, human welfare, and ecosystem integrity.

Examples of increased benefits from cooperation over scarce water resources, in particular integrated upstream-downstream management in the Jordan River basin, according to the categories by Sadoff and Grey (2002), include:

a benefits to the river: restoration of environmental flows and aquatic ecosystem, improvements in water quality of the lower Jordan, and reduced shrinking of the Dead Sea
b benefits from the river: higher water productivity from re-allocating water to other sectors than agriculture such as tourism – which also depends on the river's water quality
c benefits of reduced costs: higher return on investment when addressing water problems at their source, i.e. in the upper catchment, rather than investing in downstream remediation projects
d benefits beyond the river: cooperation over water resources may have spill-over effects into other sectors, e.g. stimulating intra-regional virtual water trade, supporting economic integration, or increasing resilience against climate risks.

The second point was addressed by Becker and Katz (2006), who estimated that the market and non-market benefits from restoring and conserving the Dead Sea alone would be of the same order of magnitude as the economic value of the current water uses, i.e., agricultural yields from irrigation with Jordan River water. Potential gains from restoring the lower Jordan River would come on top of this. The third point is currently under investigation by assessing costs and benefits of different alternatives to the Red Sea – Dead Sea Canal. The last point, virtual water trade, i.e. the trade with agricultural commodities that require enormous amounts of water for their production (about 1,000–10,000 liters of water per kg of produce) is the single most important current water management measure practiced in the Jordan region. Net imports of virtual water (VW) to Israel, Jordan and the Palestinian Authority exceed renewable internal water resources by several hundred percent (Hoff *et al.* 2006b). While currently most of the agricultural commodities and embedded virtual water are imported from the United States or Europe, there is a large potential for intra-regional VW trade.

Each of the riparian countries in the Jordan basin has different comparitive advantages, e.g. in terms of water and land availability, labor cost, technological and economic capacity and buying power. Hence, coordinated land and water allocations and management by all riparians according to these comparative advantages, and subsequent virtual water trade, could yield significant gains in overall water productivity and welfare.

When taking into account climate change scenarios and their projections of increasing spatio-temporal variability of water availability, a cooperative approach to integrated land and water management becomes even more important, including "climate-proofing" of transboundary water sharing arrangements.

As in the case of South Africa (see green-blue water section of this chapter), science provides numerous suggestions for improved land and water management, but the political situation currently prevents the implementation of basin-wide green-blue water principles in the Jordan region. While some NGOs promote multilateral water projects, governmental institutions – in particular those in Israel – are generally not willing to share data and information with the other countries. Ideally a basin-wide management institution or commission, such as established in other transboundary river basins, would be made responsible for coordinated management and planning of land and water resources.

10.5 Tana River basin management: addressing upstream-downstream links

Kenya is a water-scarce country, with an average water availability of about 650 m^3/cap year. The Tana basin is faced with acute water scarcity (WRMA 2006a). Just as is the case in the Jordan basin, high rainfalls are limited to the upper catchment, and precipitation declines towards the lower reaches of the river. The Tana headwaters (water towers) receive more than 2000mm of annual rainfall, while downstream areas receive less than 600mm. Under increasing water scarcity, any changes in runoff generation in the uplands have severe effects for downstream water users: hydropower production in the Tana basin, for example, provides more than half of Kenya's electricity. About 80 percent of the municipal water demand for Nairobi is met from transfers of Tana water. Irrigation in the Tana basin – also for export production – is growing rapidly. The Water Resources Management Authority of Kenya (WRMA) states that there is already "conflict due to over abstraction of water, especially in the upper zones of the catchment" (WRMA 2006b).

Ongoing land use changes in the headwaters, in particular deforestation, e.g. for marijuana cultivation, are associated with increasing runoff, but more importantly with increasing erosion and subsequent siltation of downstream reservoirs. These reservoirs, which are central for hydropower and municipal and irrigation water supply, are subject to rapid siltation and associated reduction in reservoir storage volume at a rate that is an order of magnitude higher than originally anticipated (Hoff *et al.* 2007). Any upland erosion reduction would have positive impacts on downstream water storage and availability in these reservoirs.

However, a thorough assessment is needed to quantify the overall effect from any upland intervention and possible tradeoffs between different ecosystem services affected, in terms of erosion reduction on one hand, and changes in runoff generation, ground water recharge[6] and water availability on the other hand. If, for example, UNEP's billion-tree-campaign leads to major afforestations in the upper Tana, severe losses in downstream runoff may result.

Again, as in the Jordan River basin, the green-blue water concept can provide a way forward, by adding green water to the supply of "manageable water." As in most parts of Africa, the Tana basin is dominated by rainfed agriculture with low green water productivity. If unproductive water losses are reduced and green water flows shifted to productive transpiration (vapor shift), food production can increase significantly, by a factor of two and more without compromising downstream water availability (Falkenmark and Rockström 2004).

The Green Water Credits (GWC) project demonstrates the potential for improved upland management to increase downstream water availability. In its pilot phase, the project has evaluated the downstream effects of different WOCAT-type interventions, e.g. conservation agriculture and rainwater harvesting and compared these "soft path" (Gleick 2003) solutions to the conventional "hard path" structural engineering approach, which in the Tana basin promotes additional reservoirs downstream of the existing ones. Like the Red Sea – Dead Sea conduit in the lower Jordan, additional reservoirs in the lower Tana will not tackle the root causes of water scarcity, many of which are located upstream.

Green water management in this case also can be interpreted as an attempt to conserve or rehabilitate ecosystems (natural infrastructure) and their water-related services. In particular, the poor smallholder farmers in the uplands depend on these ecosystems and the services they provide. Also, like in the Jordan basin, these rural poor can benefit directly from improved land and water management. If this is promoted by Payments for Environmental Services, it can provide additional income and strengthen land rights (see PES section of this chapter).

The next step in the GWC project will be a combination of hydrological analysis of different soft-path and hard-path interventions with economic information for basin-wide cost-benefit and trade-off analyses, applying green-blue water principles. An initial example of such an analysis for the Tana basin was provided by Emerton and Bos (2004), who calculated the downstream costs of existing (newly planned) reservoirs to be in the order of $27 (additional $19) million, due to losses in floodplain agriculture, water for livestock, fisheries, mangroves, and other side effects of reservoir construction.

The water sector reform in Kenya, initiated through the Water Act in 2002, and new water management rules, under which water is increasingly viewed as an economic good, provide an appropriate legislative framework for a widened IWRM approach at basin level. As part of the decentralization process, a new Water Resource Management Authority (WRMA) has been established with regional branches for the six major catchments in Kenya (Tana being one of them). Each of these is currently developing a catchment management strategy, which provides the major avenue for entering green-blue water principles into basin management. The newly established water user associations, in which various stakeholder groups from all parts of the basin are represented, provide an opportunity for a participatory process when detailing the catchment management strategies. The

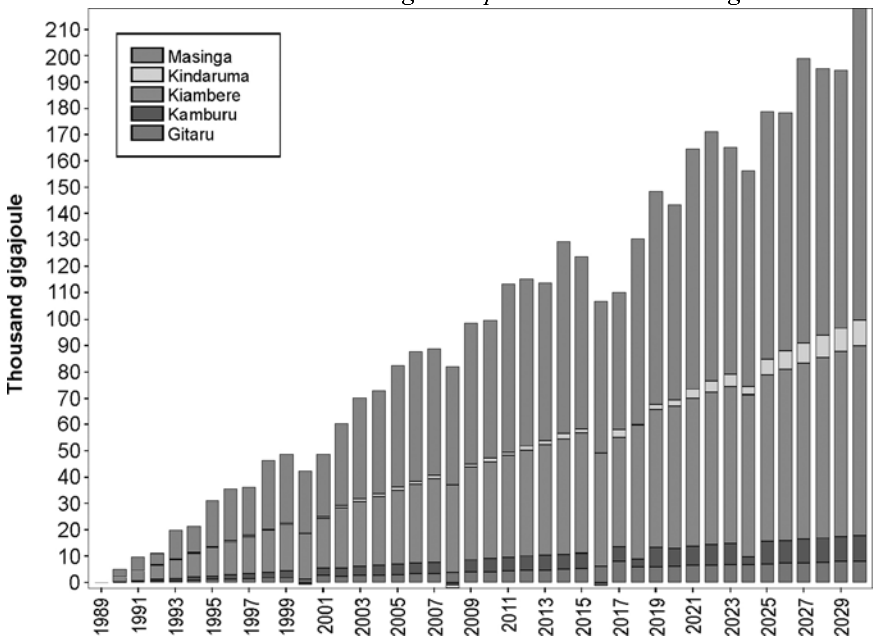

Figure 10.4 Initial results from the Water Evaluation and Planning (WEAP) tool in the Green Water Credits Project, projecting future increase in hydropower production when assuming uniform reduction of erosion by 50 percent across the upper Tana catchment and associated reductions in reservoir storage losses (Hoff *et al.* 2007).

water user associations are expected to play an important role in the design and implementation of green-blue water measures and PES schemes by providing a bottom-up community perspective.

Surveys indicate that another pre-requisite for successful implementation of economic and cost-recovery principles may be present now in Kenya, i.e. the willingness to pay, expressed by major water users, e.g. large irrigators: MWI (2005) indicates that there is a positive trend for these groups to accept water use charges if accompanied by significant improvements in water resource management.

10.6 Payments for environmental services: how to make the green-blue water approach work

From the previous sections, the green-blue water approach emerges as a useful extension of the IWRM framework for various regional water scarcity situations. The green-blue water approach provides a starting point for assessing and eventually internalizing downstream costs and benefits of upland management, taking into account a range of water-dependent environmental services.

Such a basin-wide cost-benefit assessment can start from the classification of direct and indirect uses of green and blue water, provided by Falkenmark and Rockström (2004):

If the provision of water for downstream users is interpreted as an environmental service controlled by upland farmers, compensations or rewards may provide incentives to improve or maintain this service.

The green-blue water approach helps us to understand the upstream-downstream links and to identify sustainable management practices from a basin perspective. Payments for environmental services (PES), based on this knowledge, can facilitate the adoption of best practices by upland farmers, if otherwise the return on investment is uncertain or delayed into the far future – see the analysis by Pagiola (1996) which suggests that in semiarid regions of Kenya it would take almost 50 years to recover the costs of soil conservation structures. While currently payment schemes are often tied to public funding, ideally PES funds are generated by the downstream beneficiaries themselves. But this is only likely to happen if these are (convinced of the benefits and) economically strong, such as the national hydropower company (KenGen) and Nairobi Water in the case of the Tana River, or tourist operators in the national parks in the nearby Mara River basin, which critically depend on upstream water releases in the dry season for wildlife migration.

Other examples of strong downstream beneficiaries are found in South Africa, where large commercial farms are often located downstream in river basins, or in China where larger cities are often located in the lower part of river basins. Eventually, also the state of Israel can be seen as an economically strong downstream beneficiary in the Jordan River basin, with a per capita GDP 10 times higher than that of all upstream riparians. These types of upstream-downstream relationships provide a test bed for payment schemes related to water provision as an environmental service.

WATER FLOW, WATER USE	*GREEN*	*BLUE*
DIRECT	ECONOMIC USE Rainfed food, timber fibres, fuelwood, pastures, etc.	ECONOMIC USE irrigation, industry, domestic
INDIRECT	ECOSYSTEM SERVICES Wetlands, grasslands, forests, terrestrial, biodiversity, climate regulation	ECOSYSTEM SERVICES aquatic freshwater habitats, biodiversity, resilience

Figure 10.5 Indirect and direct uses of green and blue water (after Falkenmark and Rockström 2004).

Payments for environmental services (PES) have been established for different types of services, such as carbon sequestration, biodiversity and landscape conservation, and also provision of water. Pagiola *et al.* (2007) and Börner *et al.* (2007) provide examples from Nicaragua (silvopastoral land use) and Brazil (forest and agricultural land use) for increasing carbon sequestration and biodiversity.

Water-related PES schemes until now have mostly been limited to Latin America, e.g. Costa Rica, Guatemala or Ecuador, mostly compensating upland farmers for the conservation and sustainable management of forests and for reforestation to sustain water provision for downstream uses (Emerton *et al.* 2003, Chomitz *et al.* 1998). While such schemes have often assumed improved and more regular water yield from maintaining or re-establishing forest, science has provided ample evidence (e.g. Calder 2005) that this image is misleading. While it may be true for cloud forest that trees intercept more atmospheric moisture than other vegetation, a more thorough analysis of the hydrological effects of forests or deforestation/afforestation is warranted in most cases (see green-blue water section of this chapter).

Only a few examples of water-related PES schemes are known from Africa, such as the Working for Water program[7] in South Africa, which pays and provides jobs for the poor, for eradicating water-intensive invasive alien vegetation. In principle, the poor can benefit in several ways from payments received, if PES schemes are designed well: payments enable them to invest and diversify their activities, to increase their productivity and to strengthen resilience to climate and other risks. Payments to farmers for improved upland management also may strengthen informal or formal land rights of the farmers, which in turn may promote further sustainable management that protects their very resource base.

In the Tana basin in Kenya, the Green Water Credits (GWC) project assesses eco-hydrological upland-downstream links and the costs and benefits of different management interventions as a basis for PES schemes that could simultaneously increase income for upland farmers and downstream water availability. The GWC approach will feed into the Tana Catchment Management Strategy, by allowing a comparison of marginal costs for a unit of water provided or saved, for different upland or downstream interventions. In the context of Kenya's ongoing water sector reform, that information can feed into the process of setting cost-recovery water use charges, by taking into account costs for catchment management and source protection. It also can support more stringent incentive schemes, such as the proposed 5 percent reduction in water charges for those irrigation farmers that adopt best conservation practice (Hoff *et al.* 2007).

10.6.1 The Green Water Credits project[8]

Green Water Credits (GWCs) are based upon the green-blue water concept as described above. GWCs are payments, rewards or compensations, in cash or kind, made to rural people in upland watersheds for specified management activities.

In the uplands, GWCs provide cash income, which can help to diversify livelihoods, increase productivity of farming and reduce vulnerability to external pressures such

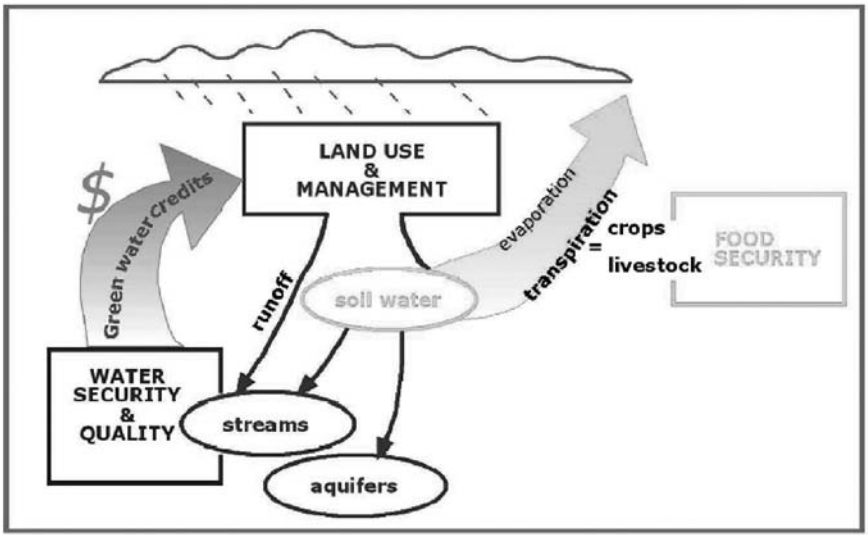

Figure 10.6 Green Water Credits scheme (Dent and Kauffman, 2007).

as climate change. Downstream, GWCs can contribute to water security, flood or drought mitigation, increased environmental flows, and improved water quality.

Goals of the GWC project in the Tana basin include:

- a quantitative understanding of upstream-downstream links and cumulative effects of different interventions, by using a set of hydrological and water management models and possibly also remote sensing applications;the identification and involvement of downstream beneficiaries, e.g. hydropower, municipal water users, irrigators, ecosystems
- the identification, characterization of livelihoods, and involvement of "upland managers," in particular smallholder farmers
- the assessment of different interventions for their costs and benefits from the local and catchment perspective
- the participatory development of PES schemes (including intermediaries such as microfinance institutions) that provide income opportunities by compensating or rewarding upland farmers for implementing or continuing downstream-friendly measures; and
- empowering and supporting local institutions in establishing and maintaining PES schemes;

(Source: Dent *et al.* 2007.)

With increasing recognition of the need for sustainable upland management as part of IWRM, additional funding will be required for these activities. The key water management institutions in Kenya, Ministry of Water and Irrigation (MWI) and Water Resource Management Authority (WRMA), concluded that "fees and water user charges are not seen as a mechanism to finance water resources infrastructure development or necessary catchment conservation activities." MWI (2005) suggests that the estimated costs for protecting catchment areas and building infrastructure, would amount to KSh 2–5 billion per year, which cannot be covered by the traditional type of revenue collection from water users.

Here again, the green-blue water approach can provide a way forward, through a more holistic approach, which goes beyond conventional user charges and taxes. In addition to sanctioning, or charging for, detrimental streamflow reduction activities, beneficial activities are rewarded through payments for environmental services, within the same green-blue water framework. This approach widens the potential funding base for catchment management activities. Going even one step further, also international funding for afforestations related to the clean development mechanism (CDM) could be directed towards sustainable land and water management: additional water demands from CDM-related afforestations could be quantified according to the green-blue water principles and become part of basin-wide financial schemes in support of improved management.

Eventually, such a comprehensive basin management approach that encompasses several environmental services could increase the overall benefits derived from scarce water resources by integrating land use, climate mitigation and adaptation activities with IWRM (or improve the environmental services index – see Pagiola *et al.* 2007).

10.7 Conclusions and policy implications

There is an increasing body of knowledge about the biophysical links between upland green water management and downstream water availability (and quality, which is not part of this chapter), as demonstrated in the previous sections for the Jordan and Tana River basins. The situation of these two rivers is typical for many so-called "dryland" basins around the world, in that most of the runoff is generated in the upland watershed which experiences increasing land and water use pressures, while downstream activities depend on stable blue water flows from the upper catchment. There is a large number of basins like the Jordan or Tana that are becoming closed basins, with all available blue water resources allocated, and any re-allocation perceived as a zero-sum-game.

Green-blue water science is beginning to address the cumulative downstream effects of the full range of upland interventions. By integrating eco-hydrological quantifications of green and blue water fluxes and productivities with socioeconomic assessments of the associated costs and benefits in terms of the different ecosystem services affected, the new emerging knowledge can support a widened IWRM approach in various "drylands." The practical implementation of this green-blue water knowledge requires a nested approach, scaling up from local pro-poor interventions that need to be embedded in meso-scale catchment management, all the way up to basin-scale planning.

In order to mainstream green-blue water knowledge into ongoing IWRM planning, a new level of cooperation between institutions will be required to overcome the traditional sectoral management approach, in particular the separation of land and water management in different ministries, authorities, and extension agencies. The strong interest of our institutional partners in the green-blue water approach, in the Green Water Credits Project (in East Africa), the GLOWA Jordan River Project and other initiatives, indicates an increasing awareness that more integrated management is required to meet the growing challenges of water scarcity, projected to be aggravated in many "drylands" by climate change.

However, while national policies begin to address integrated water and land management across scales, international cooperation remains difficult. In conflict situations, such as in the Jordan River basin, another level of water crisis or even more severe extreme events may be required before riparians may agree to coordinate their water and land management activities. Also in less critical transboundary contexts, such as in eastern Africa, green-blue water projects are likely to be limited to national contexts, avoiding the additional difficulties when involving institutions from several countries.

Adoption of the green-blue water approach and implementation of beneficial measures can be facilitated through financial or other rewards or compensations, following the experience with PES schemes from other sectors, such as carbon sequestration. Such payments acknowledge the fact that land and water managers, in particular smallholder farmers, are not guided by sustainability principles or abstract concepts such as improved water productivity, but rather need to maximize farm income. Intelligent designs of PES schemes also can strengthen land rights, another incentive for sustainable resource use by upland farmers. Eventually, PES as part of the green-blue water approach can contribute to poverty alleviation, allocation equity and increasing overall benefits for all water users in a basin.

Where economically strong downstream beneficiaries are identified, and provided with convincing scientific evidence about green-blue water links in the basin, they may join PES schemes and eliminate the need for continued public funding. There is in fact a better chance to identify and involve direct downstream beneficiaries from water-related ecosystem services, than for other more general (global) ecosystem services, such as carbon sequestration or biodiversity. Nevertheless, kick-starting water-related PES schemes will often require initial external funding, e.g. from international donors, such as in the Green Water Credits project. Longer term funding for sustainable green-blue water management as part of IWRM can possibly be generated by linking PES schemes to the CDM-related afforestations.

GWC-type integrated research needs to inform any potential PES-CDM or other upland-downstream schemes, in order to evaluate basin-wide bio-physical and socioeconomic costs, benefits and tradeoffs, and ensure that other ecosystem services supporting water and food security, livelihoods, and sustainability are not compromised.

Notes

1 www.unep.org/billiontreecampaign/

2 www.wocat.org/databs.asp
3 www.relma.org
4 www.unesco-ihe.org/ssi/
5 GLOWA: Global Change in the Water Cycle, www.glowa-jordan-river.de
6 Knowledge about the sustainable yields of aquifers is limited, and not sufficiently addressed in water management plans.
7 www.dwaf.gov.za/wfw/
8 www.isric.org/UK/About+ISRIC/Projects/Current+Projects/Green+Water+Credits.htm

References

Barnett T. P., Adam, J. C. and Lettenmaier, D. P. (2005) Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature,* 438: 303–9.

Becker, N. and Katz, D. (2006) Economic evaluation of resuscitating the Dead Sea. *Water Policy*, 8, 4, 351–70.

Börner, J., Mendoza, A., Vosti, S.A. (2007). Ecosystem services, agriculture, and rural poverty in the Eastern Brazilian Amazon: Interrelationships and policy prescriptions, Ecological economics, 64, pp. 356–373.

Calder, I. R. (2005) *Blue Revolution*, London: Earthscan.

CCCD (1997) *Summary guide to the terms of the Watershed Agreement,* Arkville, NY: The Catskill Center for Conservation and Development.

Chomitz, K. M., Esteban, B. and Constantino, L. (1998) *Financing environmental services: the Costa Rica experience and its implications.* Environmentally and Socially Sustainable Development, Latin America and Caribbean Region, World Bank.

Dent, D. L.and Kauffman, J. H. (2007). *The spark has jumped the gap: green water credits proof-of-concept*. Green Water Credits Report 7, World Soil Information, Wageningen, The Netherlands: ISRIC.

DeWit, M. and Stankiewicz, J. (2006) Changes in surface water supply across Africa with predicted climate change. *Science Express*, 2 March 2006.

Döll, P. and Flörke, M. (2005) *Global-scale estimation of diffuse groundwater recharge – model tuning to local data for semi-arid and arid regions and assessment of climate change impact*. Germany: Frankfurt Hydrology Paper 03.

DWAF (1999) *Streamflow reduction allocations, combined licensing and authorisation guidelines.* Pretoria, South Africa: Department of Water Affairs and Forestry.

Emerton, L. (2003) *Tana River, Kenya – integrating downstream values into hydropower planning, case study in wetland valuation #6*, Gland, Switzerland: IUCN.

Emerton, L. and Bos, E. (2004) *Value – counting ecosystems as water infrastructure*. Gland, Switzerland: IUCN.

Falkenmark, M. and Rockström, J. (2004) *Balancing water for humans and nature*. London: Earthscan.

Falkenmark, M. and Rockström, J. (2005) *Rain: the neglected resource.* Swedish Water House Policy Brief Nr. 2. SIWI, Stockholm, Sweden.

Gerten, D. *et al.* (2005) Contemporary green water flows: simulations with a dynamic global vegetation and water balance model. *Physics and Chemistry of the Earth,* 30: 334–8.

Gleick, P. (2003) Global freshwater resources: soft-path solutions for the 21st century. *Science*, 302, 5650: 1524–8.

GWP (2000) *Integrated water resources management.* Global Water Partnership TAC background paper No 4, Stockholm, Sweden.

Haddadin, M. (2006) *Water resources in Jordan*, *evolving policies for development, the environment, and conflict resolution.* Washington, D.C.: RFF Press.

Haim, D., Shechter, M. and Berliner, P. (2008) Assessing the impact of climate change on representative field crops in Israeli agriculture: a case study of wheat and cotton. *Climatic Change*, 86: 425–0.

Hasnain, S. I. (2004) Glacier meltdown. *New Scientist,* 182: 2446

Hayward, B. (2005) *From the mountain to the tap: how land use and water management can work for the rural poor.*, Research Report, UK Department for International Development.

Hoff, H., Droogers, P., Kaufman, S. and Noel, S. (2007) *Scenarios for water supply, demand and management in the Tana River Basin.* Green Water Credits Report No 4., Wageningen, The Netherlands: ISRIC.

Hoff, H., Noel, S. and Droogers, P. (2007) *Water use and demand in the Tana Basin: analysis using the water evaluation and planning tool (WEAP*). Green Water Credits Report 4. ISRIC – World Soil Information, Wageningen, The Netherlands: ISRIC.

Hoff, H., Küchmeister, H. and Tielbörger, K. (2006a) *The GLOWA Jordan River Project – integrated research for sustainable water management.* IWA Water Environment Management Series No 10.

Hoff, H., El-Fadel, M. and Haddadin, M. (2006b) *Expert statement on political factors of virtual water trade.* Research Initiative on Virtual Water Trade. Bonn, Germany: German Development Institute.

IPCC (2007) *Impacts, adaptation and vulnerability.* Intergovernmental Panel on Climate Change, Fourth Assessment Report, Working Group II. Cambridge: Cambridge University Press.

Kabat, P. *et al.* (2004) *Vegetation, water, humans and the climate.* Heidelberg, Germany: Springer Verlag.

Kunstmann, H., Suppan, P., Heckl, A. and Rimmer, A. (2007) Regional climate change in the Middle East and impact on hydrology in the Upper Jordan catchment. *Proceedings of Symposium HS2004 at IUGG2007*, July 2007, Perugia, Italy, IAHS Publ. 313, 141–9.

Menzel, L., Teichert, E. and Weiss, M. (2007) Climate change impact on the water resources of the semi-arid Jordan region, *Proceedings of the Third International Conference on Climate and Water*, 3–6 September 2007, Helsinki, Finland.

MWI (2005) *Report on operationalisation of the Water Act 2002 in water resources management*. Nairobi: Ministry of Water and Irrigation.

Oweis, T. Y. and Hachum, A. Y. (2004) Improving water productivity in the dry areas of West Asia and North Africa. In Kijne, J. W., Barker, R.,and Molden. D. (eds), *Water productivity in agriculture: limits and opportunities for improvement*. Colombo, Sri Lanka: CABI.

Pagiola, S. (1996) Price policy and returns to soil conservation in semi-arid Kenya. *Environmental and Resource Economics,* 8: 255–71.

Pagiola, S. *et al.* (2007) Paying for the environmental services of silvopastoral practices. *Ecological Economics,* 64: 374–85

Phillips, D. *et al.* (2006a) *Trans-boundary water cooperation as a tool for conflict prevention and broader benefit sharing*, Global Development Studies No. 4. Stockholm: Ministry for Foreign Affairs.

Phillips, D., Attili, S., McCaffrey, S. and Murray, J. S. (2006b) The Jordan River Basin: potential future allocations to the co-riparians. *Water International*, in press.

Rockström, J. *et al.* (2005) *Sustainable pathways to attain the millennium development goals: assessing the key role of water, energy and sanitation.* SEI, Stockholm: SEI.

Rockström, J. *et al.* (2007) Future water availability for global food production: the potential of green water for increasing resilience to global change. Submitted to *Water Resources Research.*

Rost, S. *et al.* (2007) Agricultural green and blue water consumption and its influence on the global water system. Submitted to *Water Resources Research.*

Sadoff, C. W. and Grey, D. (2002) Beyond the river: the benefits of cooperation on international rivers. *Water Policy,* 4, 5: 389–403.

Smakthin, V., Revenga, C., and Döll, P. (2004) *Taking into account environmental water requirements in global-scale water resources assessments*, Comprehensive Assessment Research Report 2, Colombo, Sri Lanka.

Soussan, J. and Noel, S. (2005) *Poverty reduction and water management*. Joint Agency Paper for the Poverty Environment Partnership. New York: UNDP.

Vörösmarty, C. J., Green, P., Salisbury, J. and Lammers, R. B. (2000) Global water resources: vulnerability from climate change and population growth. *Science,* 289: 284–88

WRI (2007) *Earthtrends.* Online. URL: http://earthtrends.wri.org

WRMA (2006a) *Tana water catchment area*, Annual Report 2005–2006. Nairobi: Water Resources Management Authority.

WRMA (2006b) *Tana catchment management strategy* Nairobi: Water Resources Management Authority.