22 Achieving Food and Environmental Security: Better River Basin Management for Healthy Coastal Zones

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Abstract

The Millennium Development Goals call for the eradication of extreme poverty and hunger while ensuring environmental sustainability. Water is essential for food production and sanitation – key factors in poverty reduction. At the same time, it is increasingly difficult to ensure clean water to maintain ecosystem services. The challenge is to find ways of managing water in order to meet both these goals in a balanced way. This water–food–environment dilemma is exceedingly clear in the coastal zone because of increasing urban demands for water, with agriculture remaining an important component of rural livelihoods, and the dependence on water by some of the most valuable ecosystems of the world that are essential for the well-being of society.

Driving forces affecting this water–food–environment nexus are increases in population and income and changing dietary patterns, which highly influence food production and water-use patterns. In response, there have been many positive trends such as overall better nutrition, an increase in overall food production and water productivity, and increased global trade in food products, thus helping in food distribution. On the other hand, there are some very disturbing trends. South Asia and sub-Saharan Africa still fall below the level required to 'lead a healthy and reproductive life' and water could be much better used for providing food security. An increased number of water bodies are becoming depleted, polluted and non-productive, negatively affecting both aquatic and terrestrial ecosystems.

Coastal zones are particularly vulnerable as they are susceptible to rapid changes both from within the area and from outside – shock events like tsunamis plus consistent pressure from upstream water development and use. Coastal zones bear the brunt of upstream water development, reduced flows and pollution loads, yet river basin water management has been concentrated in upstream areas and very often the coastal zone is neglected or considered separately. Thus, in order to achieve and maintain healthy coastal zones, agricultural water management has to be able to respond to rapid changes from within coastal zones to maintain a balance of food, livelihood and environmental interests, and coastal zone interests must be firmly represented in overall river basin management.

Introduction

Achieving the Millennium Development Goals (MDGs) on poverty, hunger[1] and environment[2] simultaneously is a challenge, as the goals seem to be in direct conflict with each other, particularly when reflecting on the role of water management. This is because a reduction in poverty and hunger requires water for agriculture while environmental sustainability requires sufficient water for ecosystems to prosper. The use of water for agriculture has imposed stress upon many important ecosystems – especially rivers and coastal systems. There is therefore a need for more water to feed people, more water to reduce poverty and more water to sustain natural ecosystems. And because of increasing water demand for cities and industries, there will be less water to go around, especially with the predicted 2 billion more people to feed in the next 25 years. The challenge is to find ways to manage water to meet the MDG targets on poverty, hunger and the environment.

This dilemma is exceedingly clear in coastal zones. These areas bear the brunt of upstream river basin development, receiving the leftover drainage flows and pollution loads. Almost 40% of the world's population lives within 100 km of a coastline. These coastal inhabitants live on only 22% of the world's available land mass (WRI, 2001) and population pressure is growing. Coastal zones are areas of intense urban and agricultural water needs, but are also home to valuable aquatic ecosystems, essential to human well-being. Around the globe a total of 25 biodiversity hot spots have been identified, of which 23 are at least partly in the global coastal zone (Shi and Singh, 2003).

Coastal zones are highly susceptible to river basin water stress because changed hydrologic flow regimes and increased pollution loads are felt at the tail end of river systems. A global study of environmental water stress indicates that the problem is severe and growing, posing increasing threats to coastal areas (Smakhtin *et al.*, 2004). Therefore, the health of the coastal zone is a good indicator of river basin health. In spite of calls for integrated water resources management (IWRM), the coastal zone is often looked at in isolation, and its importance underestimated compared to upstream activities in the river basin perspective.

Water for Food: Key Trends and Driving Forces

A starting point in the water–food–livelihood–environment equation is to recognize that food consumers are key drivers of agricultural practices. To produce 1 kg of grain, plants must transform between 400 and 5000 l of water – based on the crop type, climate and management practices – into water vapour through evapotranspiration. Depending on diet and where food is grown, each person is responsible for the conversion of 2000 to 5000 l of water each day into water vapour (Renault and Wallender, 2000). The 2–5 l/day for drinking and 50–200 l/day for household use seem insignificant when compared to the amount of water required for food production.

So, how much water is needed for agriculture to feed the world? Agricultural withdrawals from rivers, wetlands and groundwater are in the order of 2500 km^3/year – in many developing countries, this is more than 90% of all water withdrawn for human uses. From another perspective, of the approximately 100,000 km^3/year

[1] The MDG targets on poverty and hunger aim to halve, between 1990 and 2015, the proportion of people whose income is < US$1/day (Target 1); and halve, between 1990 and 2015, the proportion of people who suffer from hunger (Target 2) (UN, 2002).

[2] The MDG targets on environmental sustainability aim to integrate the principles of sustainable development into country policies and programmes and reverse the losses of environmental resources (Target 9); halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation (Target 10); and have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers (Target 11) (UN, 2002).

reaching Earth's surface as rainfall, only 40% or 40,000 km^3 represents the renewable water resource in the form of river run-off and groundwater storage. Of this amount, some 10% or 3800 km^3 is diverted from its natural courses, of which 2500 km^3 is withdrawn for irrigation (based on Shiklomanov, 2000). Presently, approximately 7000 km^3 of water withdrawn from the various water sources is converted to evapotranspiration to produce food (Rockström *et al.*, 1999, 2003).

Provision of water is also central to the livelihood security of many rural poor. The majority of people in developing countries still depend on agriculture for their livelihoods. Approximately 70% of the world's poor live in rural areas with limited livelihood opportunities outside of agriculture (World Bank, 2004). However, the role of fishing and related activities, such as small-scale fish processing and trading, can represent a crucial element in their struggle against poverty and food insecurity, especially for women. In West Africa and in a large part of South-east Asia, for instance, small-scale fish processing and retailing activities are dominated by women. Fish are an important source of animal protein and so can contribute to reducing malnutrition, reaching towards the MDGs. Fishing can greatly improve the food security of millions of both rural and urban poor, with limited strain on water and at the same time provide livelihood security (C. Béné, Egypt 2004, personal communication).

Providing the rural poor with a reliable source of water, whether it is from small-scale water harvesting, large-scale irrigation or access to water bodies for fishing, makes it possible for them to move beyond subsistence farming. A reliable source of water prevents yield losses from short-term drought, which in sub-Saharan Africa may claim one out of every five harvests. It gives farmers the 'water security' they need to risk investing in other productivity-enhancing inputs, such as fertilizers and high-yielding and high-value crops such as vegetables.

It is clear that there is a need to change the way water is developed and managed for agriculture. Breaking old habits, recognizing where things are going well and introducing new ways of doing business are the means to achieving this change. This includes considering key shifts in activities such as fishing, which has relatively low water consumption requirements. Given the high environmental and political uncertainty that characterizes some of these regions facing water scarcity, the capacity of fishing activities to generate instantaneous gains represents an enormous advantage over farming (Béné *et al.*, 2003).

Key water–food–nutrition–livelihood–environment trends (SIWI-IWMI, 2004) are laid out in Box 22.1. These indicate that we have to reverse negative ecological and livelihood trends, mitigate water problems arising from new trends such as urbanization and enhance positive promising trends.

River Basin Drivers of Coastal Zone Change

In response to increased demand, people clear land and withdraw water from rivers and groundwater to grow more food. Water withdrawals and subsequent changes in storage, flows and evapotranspiration influence river hydrology, and consequently affect related ecosystems and the livelihoods they serve. Here we outline the main ways in which agriculture alters coastal zone ecosystems and related biodiversity. Of over 17,000 major sites globally already devoted to the protection of biodiversity, many of which are types of wetland, 45% have at least 30% of their land used for agriculture, and most of the remainder adjoin or are encompassed by agricultural lands. Around the globe, a total of 25 biodiversity hot spots have been identified, of which 23 are at least partly in the global coastal zone (Shi and Singh, 2003).

Notably, agriculture affects more than 50% of the world's more than 1267 wetlands of international importance (Wiseman *et al.*, 2003). Drainage and conversion for agricultural use are the principal and most direct causes of wetland loss globally. Globally, irrigated area continues to expand, particularly in the developing world (FAOSTAT 2000 Database), affecting river systems. By 1985, it

Box 22.1. Key trends in the water–food–livelihood–environment challenge (adapted from SIWI–IWMI, 2004)

Promising trends

- A steady increase in the per capita consumption of food leading to better nutrition for many. Average global calorie intake 1961–2000 increased from 2250 to 2800 kcal.
- A steady increase in land and water productivity – average yields increasing from 1.4 to 2.8 t/ha, and equivalent gains in water productivity from the 1960s to 2000.
- Increases in global trade in food products and consequent virtual water flows offer prospects for better national-level food security and relief of water stress. It has been estimated that global trade 'saved 11% (112 km^3) in 1995' and 19% less water use is forecast for 2025 (Fraiture *et al.*, 2004).
- Aquaculture practised in the coastal zone has been the mode for meeting the increasing demand on fisheries and is also the fastest-growing food sector in the world, with 37.9 million metric tons in 2001 (Kura *et al.*, 2004).

Very disturbing trends

- Average calorie intake in South Asia (2450 kcal) and sub-Saharan Africa (2230 kcal) remains far below norms.
- An increasing number of rivers are reduced to polluted drains because of increased agricultural production and water consumption, and inability to deal with increased pollution.
- An estimated 19% of coastal areas, including mangroves, have been converted to agriculture (including aquaculture) and urbanization, leading to loss and hindrance of natural wetlands, associated biodiversity and ecosystem functions.
- An increase in agriculture upstream and downstream has led to many pressures on the coastal belt, with outbreaks of disease and excessive loads of pollution having spin-off effects on other food chains and on general environmental conditions.
- Groundwater levels are declining rapidly because of overexploitation in densely populated areas of North China, India and Mexico.
- Increasing land and water degradation is resulting from nutrient depletion, soil degradation, salinization and seawater intrusion (de Vries *et al.*, 2003).

Double-edged trends

- Increasing withdrawals for irrigation in developing countries are positive for economic growth and poverty alleviation, but negative for the environment.
- Increasing water demand of cities and industries offers possibilities of income and employment. Developing-country cities are projected to use 150% more water in 2025 than today (IWMI, 2000). This increase often results in a shift of water out of agriculture, putting extra strain on rural communities, and leads to more polluted wastewater.

was estimated that 56–65% of available wetland had been drained for agriculture in Europe and North America, 50% in Australia, 27% in Asia, 6% in South America and 2% in Africa. Though the coastal zone in its own element has a diverse range of functions, an estimated 19% of coastal areas have already been converted for the purposes of agriculture and urbanization (WRI, 2001). Much of this has been at the expense of important coastal ecosystems that are undervalued and underappreciated. Coral reefs and mangroves were proved to be extremely valuable in lessening human loss during the recent Asian tsunami.

Closing River Basins

Especially within the last 50 years, river basins have been significantly altered to serve the needs of growing populations. As increasing amounts of water are withdrawn and depleted for agricultural and urban purposes, river basins change from an open state – where there is still available water to allocate to new uses – to a closed state, where all available water has been developed and allocated across uses (Seckler, 1996; Molden 1997). With increasing hydraulic infrastructure and conversion of land, the discharge at the terminal end of rivers decreases. Changes upstream in a basin ultimately affect the coastal zone – land-use changes, increased withdrawals and depletion of water, hydraulic structures to store and release water change flow patterns and change sediment loads, and increased pollution.

A consequence of closed basins is that a change in use in one part of a basin affects water availability in another part, often in unseen and counter-intuitive ways. The impact of an additional dam for irrigated agriculture can reduce discharge to the coastal zone. The impact of one small water harvesting system may not be felt, but the impact of many may be considerable and reduce the amount of water available to other users in rivers, much like the impact of large dams (Batchelor *et al*., 2003).

Changing land use is directly related to change in river basin hydrology (Calder, 1998). A net change in evapotranspiration from land cover change affects the volume and temporal pattern of river flows. A change from arid to irrigated land increases evapotranspiration and subsequently decreases river flow. A change from forest to rainfed land in the humid tropics may have the reverse effect of increasing the volume of discharge in a river. Dams and reservoirs alter patterns of flow, often dampening patterns of high and low flows. With extensive development of land and water river flow patterns in terms of volume, the temporal pattern of discharge and pollution loads are very different from natural flow patterns.

To determine whether a basin is closed requires knowledge of flow requirements or allocations for environmental purposes. Some important functions of rivers are to flush out sediments, salts or pollution. Coastal estuaries and their fisheries depend on fresh water and river sediments. In many river deltas, dry-season flows are diminished, leading to increased salt water intrusion. Coastal aquatic ecosystems and fisheries, dependent on sustaining these ecosystems, are susceptible to changing patterns of salinity and flows. The boundaries of river basin management need to be extended to where they influence coastal systems and ecosystems. Basins are considered to be open if water remains in excess of these allocations or requirements. They become closed when only the environmental allocation remains. Some basins have already overcommitted their water to various uses, and are not able to meet environmental consequences. The Yellow and Colorado rivers (USA) and Amu and Syr Darya rivers (Central Asia) are examples of overcommitted rivers.

Scale Issues

One of the biggest difficulties in understanding water resources is the prevalence of cross-scale effects that often happen in a counter-intuitive manner. For example, drip and sprinkle irrigation are widely regarded as water conservation practices because less application to crops is needed, and drainage flows from fields are reduced. This sounds practicable and acceptable, and indeed for individual farmers it may be extremely beneficial, especially if yields and profits are boosted. But the story is not complete until we understand what happened to the 'saved' water. One common occurrence is that farmers use this 'extra' water to irrigate more area, and thus overall evaporation and transpiration increase and downstream flows decrease. Over time, downstream farmers and ecosystems may become dependent on return flows from agriculture. A reduction in drainage flows, without compensating flows, may cause serious downstream impacts as discussed above. The lesson is that actions taken at one scale, such as farm, field or irrigation system, typically have broader basin-wide impacts that must be clearly understood before actions are taken. The Aral Sea basin (Central Asia) is an excellent example of how upstream development caused downstream damage.

Similarly, time is an important but complex dimension. Agricultural water management builds on slow-response variables – changes in groundwater levels, salinity and pollution build-up, all of which influence long-term sustainability of these systems. The sustainability of major food production systems – the Aral Sea basin, the North China plains, northwest India – is in question. Natural ecosystems similarly show lagged responses to agriculture-driven change over many years, such as long-term changes in the geomorphological character of rivers with flow regulation, or progressive declines in inland fisheries with combined pollution, overharvesting and water abstraction effects, leading to their eventual, sometimes sudden, collapse.

Coastal Impacts of River Basin Change

When, how much, how often and in what distributional pattern water flows in rivers or moves through other wetlands affect ecosystem character and aquatic biodiversity (Richter *et al.*, 1997). For instance, major hydraulic structures to store and divert water completely change the character of parts of rivers, in some cases changing a river system to a reservoir cascade system. In other cases, rivers dry out immediately downstream of dams, or in their lower reaches, simply because of additional withdrawals and depletion of water for agriculture.

River depletion leads to several concerns. The deprivation of rich silt that fertilizes flood plains and river deltas (UNEP-WCMC, 2000), widely used for agriculture in countries such as Bangladesh and Vietnam, is one of the results of river depletion. Reduced flows as a result of damming or excessive withdrawals can lead to reduced transport of essential minerals and nutrients, which can create a drop in coastal fisheries. For example, the Aswan High Dam on the Nile caused a very significant reduction in the phosphate (by 96%) and silicate (by 82%) levels that reached the coast. This reduction combined with other factors such as increased salinity, including saline intrusion in monsoon deltas during the dry season. Reduced flows have caused significant reductions in coastal fisheries (FAO, 1995). Because of the trapping of sediments and nutrients upstream, the dense blooms of phytoplankton on the Nile Delta have been eliminated. Since this was a food source for many detritus feeders such as sardines, other pelagic fish and shrimp, their populations have been affected. The average fish catch in 1962 and 1963 was 35,000 tons, which decreased by 75% in 1969 as a result of the dam (UNEP-WCMC, 2000), although others have argued that the changes have enabled other fisheries to develop.

Both excessive sediment run-off and reduced sediment movement, often caused by upstream river basin activities, result in serious degradation of the environment. This can lead to elimination of beaches and backwaters and bring about overall degradation of coastal ecosystems. For example, the Nile Delta coastline has seen erosion rates up to 5–8 m/year (Megeed and Makky, and Stanley and Warne, 1993, cited in UNEP-WCMC, 2000). Degradation of this nature has been reported from other locations too, such as the coastlines of Togo and Benin (downstream of the Volta River) and in the regions of Camargue and Languedoc in the Mediterranean (UNEP-WCMC, 2000).

Aquaculture and fisheries

Of major concern has been the unplanned increase in aquaculture in the coastal belt, which has led to the conversion of vast areas of mangroves, salt pans and rice fields into aquaculture ponds. While affecting directly through the loss of natural habitat, this also affects the productivity of coastal fisheries as most of these ecosystems support nursery stages of fish and economically important invertebrates. Burgeoning aquaculture has brought about major problems of water pollution and disease outbreaks, which could eventually also lead to a loss of productivity and livelihoods.

A wide array of other agriculture-related factors, including overharvesting of food resources, such as those provided by inland live capture fisheries, the impacts of various forms of aquaculture and the enhanced spread of invasive species sometimes associated with agricultural systems, also play roles in altering natural ecosystems.

Shocks and natural hazards

The recent tsunami that hit the coasts of South Asia and parts of eastern Africa brought home another message on the importance of the coastal zone and its role in minimizing the risk posed by natural hazards. Preliminary investigations have already suggested that, where natural coastal ecosystems such as mangroves and sand dunes remained intact, the impacts inland have been less. This further highlights the importance of sustaining coastal ecosystems by ensuring that they get their fair share of the available water resources.

Responses – What Can Be Done?

Several courses of action in the context of river basins could help sustain coastal livelihoods and environments and meet the MDGs. These actions take place at several scales and at different locations, and are the subject of this book.

Integrating coastal zones more effectively into river basin management is surely a key to productive and sustainable coastal zone practices. This requires that coastal zone issues related to river basin management be identified, and brought into river basin management discussions. Coastal zone stakeholders – fishermen, farmers, urban dwellers and others – need to be brought into the discussion.

Within a river basin, identification and allocation of environmental flows – flows required to maintain the character of life-supporting ecosystems – are necessary. The science of environmental flows is rapidly evolving (Arthington *et al.*, 1998; Tharme, 2003; Smakhtin *et al.*, 2004). Implementation requires that these concepts be incorporated into management and allocation procedures, and there is a long way to go in this area for many basins.

Given that coastal zone ecosystems, including agro-ecosystems, will require more water, and that cities will require an increasing share, agriculture has to produce more food with less water. Increasing water productivity (Kijne *et al.*, 2003) combined with allocation procedures are important agricultural actions within a river basin.

In summary, water management in coastal areas has to balance the complex needs and objectives of a set of multiple users, while at the same time responding to pressures brought about by external changes.

Conclusions

Pressure from a growing population for more food also translates into more water and additional stress on production and ecological systems. This increasing pressure will make it more difficult for the poor, who are most vulnerable to water scarcity and environmental degradation. Continuing on our present path will mean more conflict, more environmental degradation and the persistence of poverty and food insecurity.

The deterioration of coastal habitats leads to ecosystem and livelihood loss through direct habitat loss caused by agricultural practices upstream and within coastal areas, including the rearing of crops in river deltas and conversion of inland coastal habitats for the purposes of aquaculture in an unmanaged way. All of these losses will also have adverse effects on the livelihoods of the dependent communities as well as other outside communities that reap benefits from these ecosystems.

Some solutions and responses will have to take place simultaneously and at different scales:

- changes in global policies (subsidies, trade and prices) that influence water management and use,
- changes in consumption patterns – what we eat and how we use water, and
- improved river basin management to take into consideration coastal zone needs, such as: (i) better consideration at the river basin scale of the impact of changes in water management on coastal areas; (ii) environmental flows to determine the existing levels and to determine the maximum levels of abstraction possible while ensuring that the minimum required flows will reach the coastal zone; (iii) an

increase in water productivity so that less water is used to produce more food and to reduce the wastage of water in agriculture; and (iv) managing water for multiple uses is a key issue that cannot be avoided in water management at the present time.

Difficult choices will have to be made to resolve difficult livelihood and environmental concerns. A better understanding of trade-offs and consequences of water use will better reduce controversy and uncertainty, and lead to better-informed decisions.

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