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An Ecosystem Services Approach to Water and Food Security

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Credits

This report is based on the findings of the background document, Ecosystems for water and food security, coordinated for the United Nations Environment Programme (UNEP) by the International Water Management Institute (IWMI). The full report can be downloaded at: www.unep.org/ecosystemmanagement and www.iwmi.org/ecosystems

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Preface

Overcoming hunger and meeting the nutritional needs of almost 7 billion people, rising to over 9 billion people by 2050, is a central challenge for this generation. Equally critical will be to achieve this in a way that keeps humanity's footprint within planetary boundaries.

Water scarcity is self-evidently one of the key factors that will limit food production. This is especially the case in South Asia and sub-Saharan Africa, where malnutrition and food insecurity are already widespread. In these areas, the livelihoods and well-being of poor communities are critically dependent on their farm produce and the ecosystem services from the local landscape that support their livelihoods and income.

This synthesis and background document on Ecosystems for Water and Food Security is part of UNEP's contribution to the global food crisis, pledged to the United Nations Secretary-General and developed in collaboration with the International Water Management Institute (IWMI) and other partners. Together, we identified and explored the links between ecosystems, water and food, and illustrate how resilient ecosystems can support and increase food security.

It is clear that enormous opportunities exist to increase food production in ways that make optimal and sustainable use of water and other resources. This means that we can feed a global population without massive and irreversible damage to our ecosystems. It also means that ensuring food security, managing water resources and protecting ecosystems must be considered as a single policy rather than as separate, and sometimes competing, choices.

This approach calls for a fundamental shift in perspective and a deeper understanding of the enormous economic importance of ecosystems and the broad suite of services they provide. For example, well-managed agroecosystems not only provide food, fiber and animal products, they also generate services such as flood mitigation, groundwater recharge, erosion control and habitats for plants, birds, fish and other animals.

It also requires intersectoral collaboration, because only then can policies and practices change. The overarching recommendation of this synthesis is that future sustainability requires an integrated approach to managing multipurpose agroecosystems in a landscape or river basin setting.

These ecosystems—whether they are wetlands or forests, arid pastoral lands or rice fields—represent the future of food security and resilience against shocks while offering a way towards achieving the Millennium Development Goals (MDGs) and beyond.

This synthesis report does not come in isolation. It is also a contribution to UNEP's wider work and partnerships on The Economics of Ecosystems and Biodiversity (TEEB) and a transition to a low-carbon, resource-efficient Green Economy.

Together they are all part of the urgency to evolve the sustainable development agenda forged in a previous century to reflect the new challenges and also the emerging opportunities of the 21st century.

Achim Steiner
UN Under-Secretary-General and Executive Director
United Nations Environment Programme (UNEP)

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1 The future of food

The recent rise in world food prices, which has driven over 110 million more people into poverty, is not an isolated event. Over the next several decades, food prices are predicted to rise by another 30-50% due to the inability of food production to keep up with growing demand (Nellemann et al. 2009).

We know that one of the main factors limiting future food production will be water. Particularly in the poorest areas of the world, water—accessing it, controlling and storing it—is already a problem. Currently, 1.6 billion people live in areas of physical water scarcity and this could easily grow to 2 billion soon if we stay on the present course. With the same practices, increased urbanization and changing dietary patterns, the amount of water required for agriculture in terms of evapotranspiration would increase from 7,130 km^3 today to 70-90% more (which is between 12,050 and 13,500 km^3) to feed 9 billion people by 2050 (CA 2007).

Water plays a crucial role in the delivery of many ecosystem services, including provisioning services such as biomass and crop production, as well as cultural, regulatory and supporting services (FIGURE 1). It is also a key ingredient in enhancing food production—not just through irrigation for crops, but through better management of rainwater and water for livestock, forests, fisheries and aquaculture.

Ecosystem services

Provisioning services, e.g.
- Food
- Freshwater
- Wood and fiber
- Fuel

Cultural services, e.g.
- Aesthetic
- Spiritual
- Educational
- Recreational

Regulatory services, e.g.
- Climate regulation
- Flood regulation
- Disease regulation
- Water purification

Supporting services, e.g.
- Nutrient cycling
- Soil formation
- Primary production

FIGURE 1: Ecosystem services can be divided into four main categories: provisioning, cultural, regulatory and supporting services (MA 2005). The management of agroecosystems has tended to focus on provisioning services, often to the detriment of other types of services. Ultimately, if supporting services (which operate on a much longer time scale) and regulatory services are degraded, food security will be reduced.

Maintaining healthy ecosystems to ensure water availability and other ecosystem services is essential for long-term food security (Nellemann et al. 2009). But many ecosystems are already under stress due to water withdrawals for agriculture and other purposes. Climate change is likely to exacerbate this situation in many areas—making future food security even more uncertain (BOX 1)

BOX 1

Impacts of climate change on water and food security

Most climate change predictions agree that the frequency of extreme events, such as droughts, heat waves, floods and severe storms, will increase. Some ecosystems are more vulnerable to these changes than others, but in many cases their resilience will be exceeded, leading to irreversible losses of biodiversity and various ecosystem services such as regulation of pests and water flows (Fischlin et al. 2007). Impacts on the water cycle will vary from place to place, but may include changes in streamflow, precipitation, atmospheric water content, soil moisture, ocean salinity and glacier mass balance. Some areas may experience increased annual precipitation, but this water will not be useful for food production without the means to capture and store it, and could result in increased flooding and the associated loss of crops and livestock (Bates et al. 2008).

Climate change adaptation needs to be mainstreamed into water management and agricultural planning to ensure food security targets (FAO 2009b). In general, improving resilience through an ecosystems services approach should reduce the vulnerability of food production to climate change. Land management and tree cover in catchment areas play a critical role in water yield and sediment flow (Carroll et al. 2004). In addition, efforts to improve the ability to deal with current rainfall variability and extreme climate events through increased water storage, early warning systems, and better post-harvest processing and food storage will improve the capacity to adapt to future climate change. >

BOX 1

While part of the water storage solution, particularly in Africa, may involve more large dams, these can be designed and managed to provide multiple benefits and reduce trade-offs with ecosystem services. In addition, other strategies such as better management of soil moisture, enhancing aquifer storage, and promoting small-scale, community-based storage and water harvesting need to be included—not only to reduce negative impacts on ecosystem services but also to provide greater direct benefits to the rural poor (McCartney & Smakhtin 2010).

This is especially important for vulnerable populations with low adaptive capacity; poor women and marginal social groups with limited resources, poor social networks and access to services. Efforts to mitigate the impacts of climate variability and extreme climatic events require taking into account these social inequalities, including gender-based differentiation.

In important food-producing regions, limits have already been reached or breached in ways that endanger both water and food security. For example, groundwater levels are declining rapidly in several major breadbaskets and rice bowl regions such as the North China Plains, the Indian Punjab and the Western USA (Giordano & Villholth 2007). Land degradation driven by poor agricultural land and water management practices further limits productivity gains (Bossio & Geheb 2008). In parts of the tropics, agriculture has continued to expand into forest and woodland areas, thereby reducing tree cover and compacting soil, causing higher runoff (Ong & Swallow 2004). Demand for aquaculture products like fish and shrimp continues to rise (CA 2007), endangering the health of aquatic ecosystems in many areas (Hoanh et al. 2010). Also, growing wealth, particularly in countries with emerging economies, is shifting diets towards a greater consumption of animal products, which take more water to produce than plant-based food (de Fraiture & Wichelns 2010).

Recent research suggests that declines in ecosystem services—leading to problems such as soil nutrient depletion, loss of biodiversity, soil erosion, increased vulnerability to disease and pests, and loss of buffering and storage capacity to deal with rainfall variability—have already begun to adversely affect agricultural productivity and will continue to do so at an accelerating rate under anticipated climate change. As a result, crop yields could fall 5-25% short of demand by 2050 (Nellemann et al. 2009). These problems have the greatest impact on the poorest people—those who are directly dependent on natural resources for food and livelihoods.

A new approach

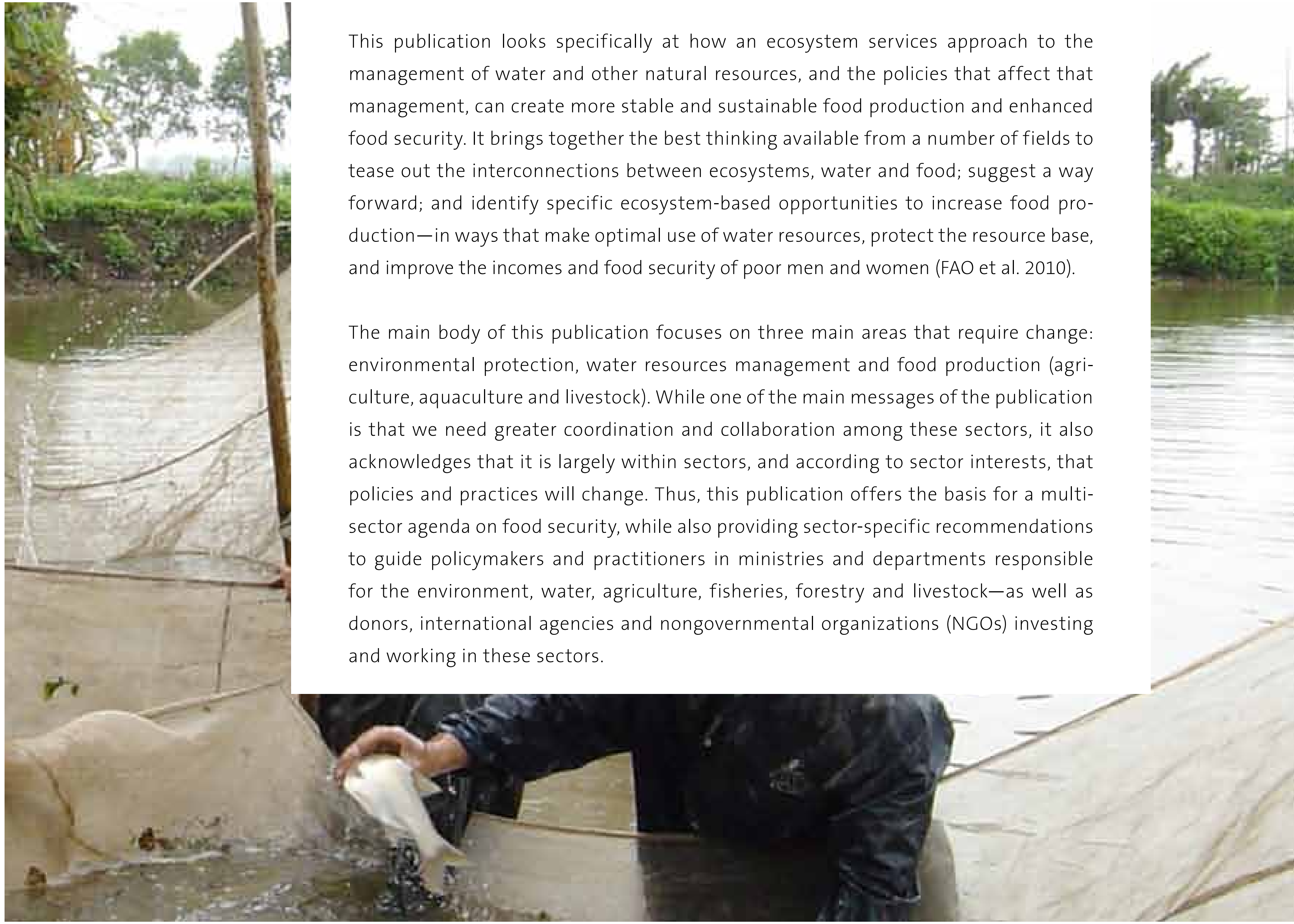
So how do we increase food production to feed the additional 2 billion people expected to swell the world's population in the next several decades? Many believe that we don't have a choice, and that we will have to sacrifice ecosystem health for food security and hope that we will find technological solutions to the resulting problems.

But what if there was another way? What if, by managing agricultural areas as ecosystems—agroecosystems—that provide a variety of services, we could enhance their productivity and sustainability? What if, by taking a broader view of our food production systems and appreciating the connections between ecosystems, water and food, we could see opportunities to increase not just "crop per drop" but also food and other ecosystem services per drop? As demonstrated in the research collected in this synthesis and detailed in the background paper upon which it is based, it is possible to feed everyone without massive and irreversible damage to our ecosystems—damage that would ultimately endanger both water and food security in the future. The knowledge is there, if only we can make the necessary changes to act on it.

Purpose of this synthesis

There is a tendency, when thinking about food security, to focus on increasing agricultural production and ensuring a supply of staple crops, such as wheat, maize, rice and tubers. But achieving food security is actually the product of many variables which include:

- physical factors such as climate, soil type and water availability;
- losses and waste along the food chain;
- management of natural resources—water, land, aquatic resources, trees and livestock—at both the farm-level and the broader landscape level; and
- policies in the many sectors that influence the ability of men and women to produce and purchase food, and the ability of their families to derive adequate nutrition from it.



This publication looks specifically at how an ecosystem services approach to the management of water and other natural resources, and the policies that affect that management, can create more stable and sustainable food production and enhanced food security. It brings together the best thinking available from a number of fields to tease out the interconnections between ecosystems, water and food; suggest a way forward; and identify specific ecosystem-based opportunities to increase food production—in ways that make optimal use of water resources, protect the resource base, and improve the incomes and food security of poor men and women (FAO et al. 2010).

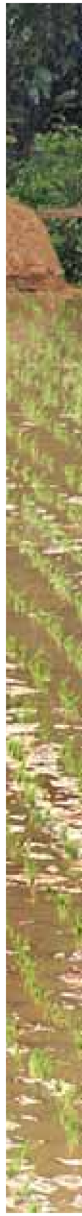
The main body of this publication focuses on three main areas that require change: environmental protection, water resources management and food production (agriculture, aquaculture and livestock). While one of the main messages of the publication is that we need greater coordination and collaboration among these sectors, it also acknowledges that it is largely within sectors, and according to sector interests, that policies and practices will change. Thus, this publication offers the basis for a multi-sector agenda on food security, while also providing sector-specific recommendations to guide policymakers and practitioners in ministries and departments responsible for the environment, water, agriculture, fisheries, forestry and livestock—as well as donors, international agencies and nongovernmental organizations (NGOs) investing and working in these sectors.

2

Ecosystem-water-food connections

Ecosystems provide food both in their natural state (e.g., capture fisheries, forest products) and in the form of managed landscapes (e.g., crop systems, agroforestry, livestock, aquaculture). Population growth, urbanization and shifting consumption patterns are putting increased pressure on water and other natural resources, and thus threaten the capacity of ecosystems to support food production and other services. Also, because the majority of the world's poor men and women directly depend on ecosystems—both natural systems and managed agroecosystems—for their food, fuel and livelihoods, they are the most vulnerable to ecosystem degradation and climate-related shocks.

Ecosystems also provide a host of services that underlie water and food security. In particular, many ecosystems (such as forests, wetlands and floodplains) provide water management functions that are crucial for a stable food supply. These include water storage, purification and regulation functions as well as flood control. Ecosystems also need water for functioning. Recognizing ecosystems as a water user, like industries and cities, is a first step in ensuring the continuation of key services provided by ecosystems.



Looking at the world as a range of ecosystems (from pristine nature to intensive agriculture) and recognizing that ecosystems provide a variety of services (FIGURE 1), can help us manage trade-offs and ensure that short-term gains (for example, in provisioning services) do not undermine services that are critical for resilience and long-term sustainability. In particular, there needs to be a shift in how we think about agriculture—from a focus on managing crop production to managing agroecosystems for multiple services.

The Millennium Ecosystem Assessment points out that the significant increases in provisioning services achieved in recent times, and, in particular, food production through agriculture, has been achieved at the expense of other ecosystem services, biodiversity and resilience of the resource base (MA 2005). The conversion of land to monocropped systems, with a high use of agrochemicals, high grazing pressure in drylands and increased diversion of water for agriculture, have had the biggest impact on the balance of ecosystem services. A better balanced delivery of ecosystem services could mean:

- more efficient use of natural resources such as water (FIGURE 2);
- a reduction in the 5-10 million hectares of farmland that are lost each year due to degradation;
- fewer yield losses as a result of pests and diseases, droughts and floods;
- increased benefits for some of the world's poorest people, particularly women and children, who tend to be more engaged in activities that are dependent on ecosystems— gathering firewood, fetching water and collecting food.

Ecosystem services are crucial to the livelihoods of the rural poor. While agriculture, forests and other ecosystems together comprise 6% of the GDP in Brazil and 11% of that in Indonesia, these ecosystem services contribute more than 89% of the GDP to poor households in Brazil and 75% to those in Indonesia, thus benefitting 18 and 25 million people in Brazil and Indonesia, respectively (TEEB 2010). Hence, there is significant potential to contribute to poverty reduction through conservation efforts and better management of agroecosystems.

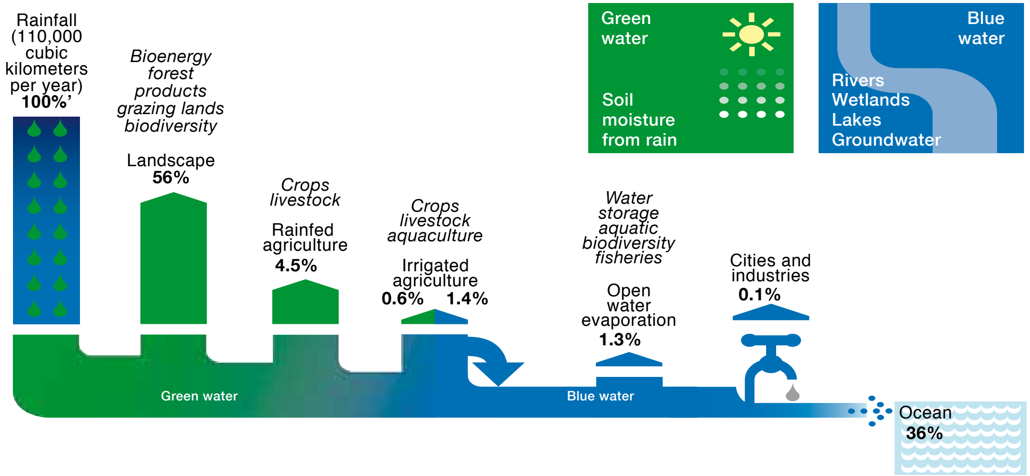


FIGURE 2: Overview of global water use by sector showing consumption of water stored in the soil profile (green water) and water stored in surface water bodies and aquifers (blue water) (CA 2007).

3

Areas for change

By recognizing healthy ecosystems as the underlying basis for sustainable water resources and stable food security, it is possible to make food supply not only more sustainable, but also:

- more productive—producing more food per unit of land and water and more benefits for poor communities, particularly women and other disadvantaged groups;
- more resilient in the face of climate-related and external shocks; and
- more compatible with sustaining other ecosystem services and wild biodiversity.

But this will require changes as to how we manage our landscapes and natural resources, such as land and water, and our food production systems.

In particular we need:

Changes in how we view our ecosystem assets. This means shifting from a focus on the protection of discrete ecosystems to management of larger landscapes—addressing them in bundles of interlinked services, including those that support food production. The ministries of environment potentially have an expanded role to play here in: (a) increasing awareness of the role ecosystem services play in water and food security, and of opportunities for enhancing a range of ecosystem services in agroecosystems; (b) promoting more considered evaluation of potential trade-offs associated with food security policy and planning; and (c) encouraging better cooperation with other sectors to improve sustainability and productivity of food supply systems.

Changes in how we manage water resources in river basins to ensure water for ecosystems and ecosystems for water. When allocating resources and planning land and water development, it is important to value the various ecosystems services including the provision of water and food, as well as other services, to avoid making unintended trade-offs—particularly trade-offs that are ultimately detrimental to long-term water and food security. In particular, assessing water requirements for ecosystems (environmental flows) and, when making allocation decisions, viewing ecosystems as water users are the critical first steps.

Changes in how we approach food production, shifting the focus from "food production systems" to agroecosystems that provide a wider variety of services. This shift applies to large-scale food production, but also has benefits for small-scale subsistence production, which is often managed by women and youth. Taking an agroecosystem approach at landscape level also makes it easier to identify and act on opportunities for synergies among crops, fish, livestock, tree and forest products. For example, the reuse of agricultural waste products, such as crop residue and by-products from processing, in animal feed, can increase the amount of food produced without increasing the amount of land and water resources required. This will also help curbing losses along the food chain (Lundqvist et al. 2008). Strategic placement of trees in agroecological landscapes can increase water infiltration and percolation, thereby improving overall water productivity while providing fuel, fodder, fruit and timber (Ong & Swallow 2004).

These changes also need to be complemented by an approach to food security that considers equitable access to resources, and the information, infrastructure and other supports that are needed for poor women and men and their families to benefit from these resources.

Concepts and tools for change

Throughout this document we refer to several concepts and tools that can support more sustainable and productive decisions, and management practices.

- Ecosystem Services (Figure 1 and Box 2): The direct and indirect benefits that humans derive from natural and managed ecosystems, such as provisioning (including food), cultural, regulatory and supporting services.
- Environmental Flows (Figure 3): The quantity, quality and timing of water flows that are necessary to sustain ecosystem services, in particular, those related to downstream wetlands and aquatic habitats, and the human livelihoods and well-being that depend on them (adapted from eFlowNet 2010).

- **Agroecosystems:** Agriculture viewed as a set of human practices embedded and part of its own ecosystem that has certain ecosystem needs, functions and services and that interacts with other ecosystems. Agroecosystem management is then the management of natural resources and other inputs for the production of food and other provisioning, cultural, regulatory and supporting ecosystem services.
- **Integrated Water Resources Management (IWRM):** A holistic approach to coordinated water development and management that seeks to achieve a balance among the objectives of social equity, economic efficiency and environmental sustainability by considering rainwater, runoff and groundwater sources in a broad biophysical and social context (adapted from GWP 2000).

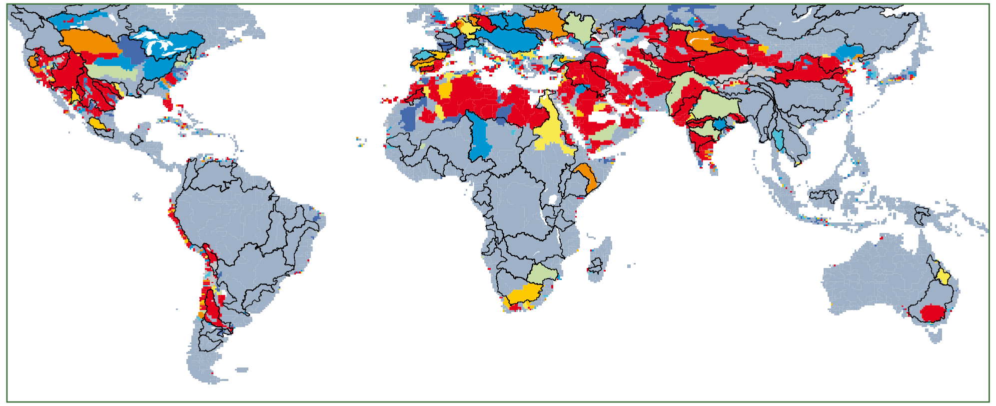


FIGURE 3: Map of a water stress indicator that takes into account Environmental Water Requirements (EWR). Areas in red show river basins where EWR are not being met. Areas in orange show river basins more likely to experience environmental water stress in the future (Smakhtin et al. 2004).

BOX 2

UNEP's ecosystem management approach

UNEP promotes an approach to the integrated management of land, water and living resources that provides a sustainable delivery of ecosystem services in an equitable manner. For food security in the short term, provisioning services are crucial, but for future and long-term secure access to food for all, regulatory and supporting services are as important. To target all ecosystem services, a holistic view is required of the links between ecosystem service delivery and human needs—an ecosystem approach.

This approach requires adaptive management, as its implementation depends on local, national or even global conditions. Hence, the UNEP Ecosystem Management Programme (UNEP 2009) is working towards a cross-sector approach that integrates landscape elements in agroecosystems and non-agricultural ecosystems, and managing these towards delivery of the full range of ecosystem services.

Valuing ecosystem services is an important tool when considering the costs and benefits of different options for achieving water and food security. Many goods and provisioning services come from non-agricultural land such as food, fodder, fiber and timber. When making decisions on water allocation, the whole range of ecosystem services, their benefits (values) and costs (social, financial, water) have to be taken into account (TEEB 2010). Well-balanced decisions can then be made about trade-offs and, ideally, ecosystem services can be enhanced (Bennett et al. 2009).

4

Environment: shifting from protection to sustainable management

Growing demands for water and food, coupled with land and water management practices that erode the natural resource base, are placing considerable pressure on ecosystems of all types and decreasing the productivity of agroecosystems. If efforts to increase food security are not approached from an ecosystem services perspective, there is the potential to compound this problem.

On the other hand, greater understanding and appreciation of the role of the services provided by a variety ecosystems, including agroecosystems, could help break the cycle of declining food production as a result of degradation and reduce the need to convert more land and divert more water to agricultural production, which would further decrease resilience and increase vulnerability.

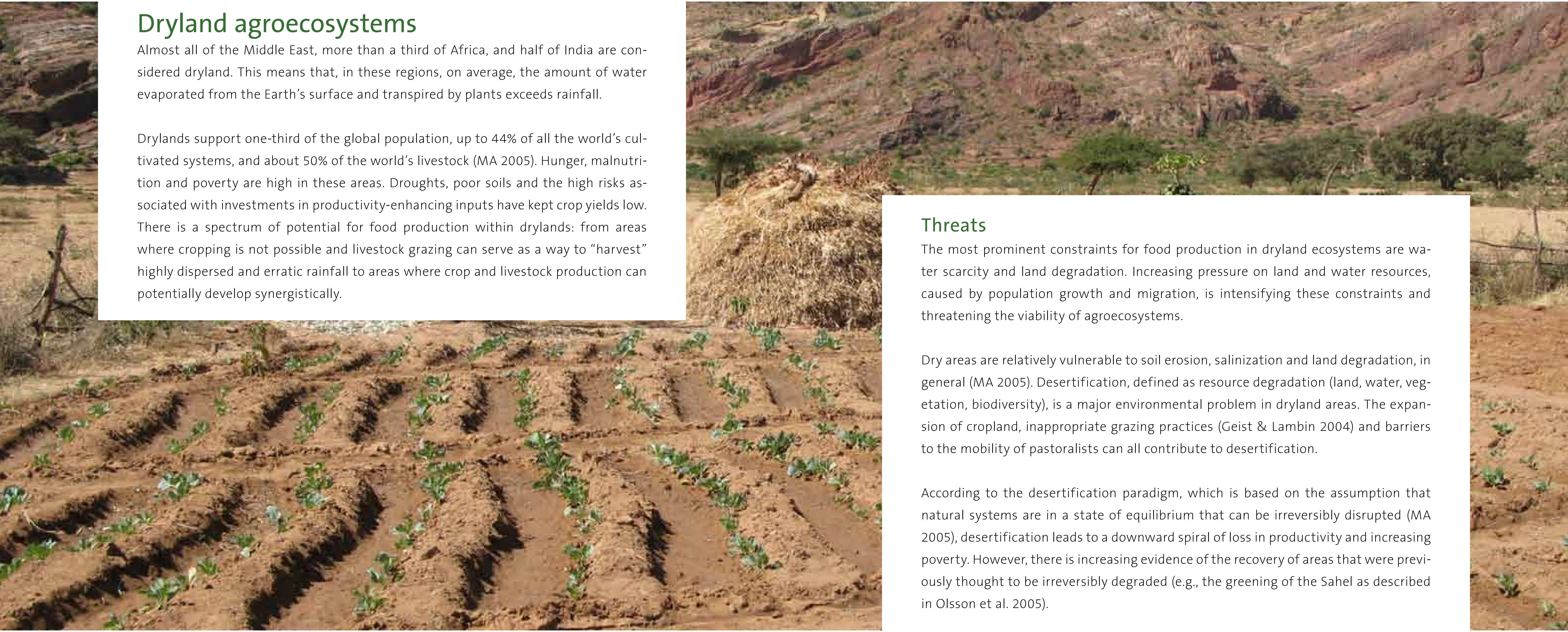
The ministries of environment may be in the best position to promote an ecosystem services approach to food security. This would involve promoting recognition of ecosystem services in food security policy and planning, and promoting better cooperation between other sectors to improve sustainability and productivity of food supply systems, e.g., promoting habitat connectivity in agricultural landscapes and ecological solutions to the threat birds and other animals pose to seedlings and crops; linkages in the management of agroecosystems and other ecosystems, such as freshwater and coastal ecosystems, to reduce waste and negative externalities; and supporting agroecosystem services and multifunctionality in food production systems. To play this expanded role, the ministries of environment would need a clear mandate and the resource and capacity building that is necessary to fulfill it.

It would also require changes in thinking and practice. In particular, taking a landscape view—moving from a focus on the protection of discrete ecosystems to promoting coherent management of larger landscapes, i.e., linked agroecosystems and non-agricultural ecosystems. This does not mean abandoning the protection of particularly fragile or threatened ecosystems, but it does mean looking at protection as one tool in recovering and maintaining ecosystem services, and considering interactions between protected areas and neighboring agroecosystems.

The range of ecosystem services, including food production, provided by agroecosystems can be enhanced with proper management and supporting policies. An important part of this support is the design and implementation of appropriate incentives for male and female farmers, fishers, forest dwellers and livestock herders to maintain and, in some cases, restore ecosystem services. Payment for ecosystem services is one option. Subsidies and support for practices that enhance food production and other ecosystem services is another—for example, better utilization of waste and by-products from food processing; integration of cropping systems with trees, livestock and aquaculture, and situations whereby degraded lands can be brought back into productive use through rangeland conservation and farming practices that restore surface vegetation and soil functions.

There is great variation among agroecosystems and the possibilities for enhancing their ability to provide food and other services. The following sections take a more in-depth look at agroecosystems in areas at the extremes of water availability—drylands and wetlands. We have chosen to focus on these systems because the majority of the world's poorest people depend on them for food and because they are some of the most vulnerable to degradation and loss of critical ecosystems services.

There are also good opportunities to sustainably boost food production in these areas while halting or even reversing the decline in ecosystem services, but acting on these will require sustainable management plans with an ecosystem services perspective. These management plans should also integrate the multiple perceptions and needs of affected communities, and a gendered perspective in order to address issues of equity arising from differential access to, ownership of, and decision-making power over natural resources.



Dryland agroecosystems

Almost all of the Middle East, more than a third of Africa, and half of India are considered dryland. This means that, in these regions, on average, the amount of water evaporated from the Earth's surface and transpired by plants exceeds rainfall.

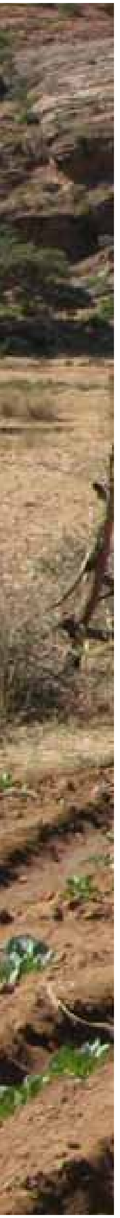
Drylands support one-third of the global population, up to 44% of all the world's cultivated systems, and about 50% of the world's livestock (MA 2005). Hunger, malnutrition and poverty are high in these areas. Droughts, poor soils and the high risks associated with investments in productivity-enhancing inputs have kept crop yields low. There is a spectrum of potential for food production within drylands: from areas where cropping is not possible and livestock grazing can serve as a way to "harvest" highly dispersed and erratic rainfall to areas where crop and livestock production can potentially develop synergistically.

Threats

The most prominent constraints for food production in dryland ecosystems are water scarcity and land degradation. Increasing pressure on land and water resources, caused by population growth and migration, is intensifying these constraints and threatening the viability of agroecosystems.

Dry areas are relatively vulnerable to soil erosion, salinization and land degradation, in general (MA 2005). Desertification, defined as resource degradation (land, water, vegetation, biodiversity), is a major environmental problem in dryland areas. The expansion of cropland, inappropriate grazing practices (Geist & Lambin 2004) and barriers to the mobility of pastoralists can all contribute to desertification.

According to the desertification paradigm, which is based on the assumption that natural systems are in a state of equilibrium that can be irreversibly disrupted (MA 2005), desertification leads to a downward spiral of loss in productivity and increasing poverty. However, there is increasing evidence of the recovery of areas that were previously thought to be irreversibly degraded (e.g., the greening of the Sahel as described in Olsson et al. 2005).



The way forward

Despite the fragility of drylands, as detailed below, there are opportunities to sustainably increase the productivity of agroecosystems in these areas.

- New technologies, new cultivars and land and water management practices, such as efficient collection of runoff and soil-based storage of moisture, can be combined to greatly increase water productivity in cropped areas and restore degraded rangelands. Cultivation of local plants, desert-adapted plants, silvopastures and perennial grasses have the potential to capture benefits from infrequent and erratic rainfall and control erosion in areas too dry to support traditional field crops.

- Securing the mobility of herds for accessing natural resources, trade routes and markets through appropriate policies that take into account transboundary herd movements, e.g., by the creation of corridors and the establishment of water points and resting areas along routes. This enables livestock keepers to get more benefits from smaller herds and prevents overgrazing and degradation caused when animals are confined to smaller areas.

- At farm and larger landscape level, the integration of crop, tree and livestock production can lead to resource recovery in the form of manure for soil fertility and crop residues and tree fodder for feed. For instance, in savannah woodlands, farmer-managed natural regeneration helps increase tree cover.

Wetland ecosystems

Most wetlands—such as lakes, rivers, marshlands, mangroves, estuaries and lagoons—host a wealth of biodiversity and support multiple ecosystem services. According to the Millennium Ecosystem Assessment, they account for about 45% of the total value of all global terrestrial ecosystem services.

While recognizing the threats from agriculture to wetlands, which are well documented elsewhere, we must also recognize the importance of wetlands for agriculture—crop cultivation, livestock and fisheries—in developing countries, and the important role that wetland agriculture plays in providing livelihood opportunities (Wood & van Halsema 2008; McCartney et al. 2010). Out of more than 500,000 square kilometers (km2) of Ramsar sites, an estimated 93% support some form of fisheries or agriculture, and 71% are facing threats due to these activities (Rebelo et al. 2010).

Different types of wetlands provide different hydrological regulatory functions, many of which are critical for agriculture. These include: water regulation (i.e., water storage, groundwater recharge and discharge, flood prevention by flow regulation and mitigation) and water quality control (water purification and retention of nutrients, sediments and pollutants) (MA 2005).

Threats

Agriculture has been a major driver of wetland loss worldwide both through water use and direct conversion. Chemical fertilizers have also caused excessive nutrient loads in some wetlands with impacts on fish and freshwater availability. Irrigation has diverted freshwater from estuaries and also reduced the capacity of rivers to transport sediments—negatively affecting fisheries, reducing coastal zone protection and sediment deposition. Irrigation development and increased water use upstream can have a devastating impact on downstream wetlands, particularly in arid and semiarid areas. The conversion of wetlands to farming use also continues relatively unabated, particularly in coastal areas. For example, in Asia, more than one-third of mangroves have been lost since the 1980s, mainly to aquaculture (38% to shrimp farming and 14% to fish farming), deforestation (some 25%) and to upstream water diversions (11%) (MA 2005).

The way forward

Certain strategies, as detailed below, can be adopted in order to realign agriculture and wetlands policies.

- Reducing pollution of downstream wetlands through improved practices for the application of agrochemicals in conjunction with integrated upstream land and water management to reduce runoff, including the use of buffer strips to simultaneously protect watercourses and provide additional products and services.

- Providing alternate livestock drinking sites away from sensitive wetland areas—as a way of protecting wetlands and as a means to reducing risks to animal health (Peden et al. 2009).

- Improving inventories, assessments and monitoring of agroecosystem change in relation to the surrounding wetlands, and application of environmental monitoring and decision support systems.

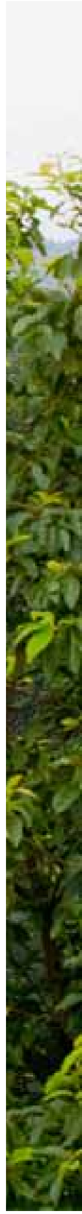
- Adopting an integrated approach to water management that considers the whole catchment, its land use, water sources (rainwater, surface water and groundwater) and sinks (enhancing infiltration and percolation with trees), and wetland ecosystems in order to balance water requirements among different ecological processes of wetland ecosystem services.

- Ensuring that interventions consider the gendered use of land and water and ecosystem services provided by wetlands, and recognize that interventions will have a differentiated impact on the livelihoods of men and women.

5

Water resources management: ensuring water for ecosystems and ecosystems for water

Water resources management directly affects ecosystem health, and, in many cases, ecosystem health underpins critical services for clean, stable water resources. Some of these services could be replaced with infrastructure—for example, water storage facilities—but at a much higher cost and often to the detriment of other ecosystem services and biodiversity. All too often trade-offs are made unwittingly.



That is not to say that infrastructure to harness water for productive uses, such as agriculture and hydropower, are not necessary. In many parts of the world, particularly where rainfall variability is already high and predicted to increase as a result of climate change, such as sub-Saharan Africa, more water infrastructure is needed to ensure food security. But these decisions can be made in such a way that they yield more benefits and have fewer ecosystem costs than in the past. For example, considering all water storage options—from small to large and including ways to maximize the natural water storage provided by aquifers and wetlands—can reduce trade-offs with ecosystem services and, in some cases, may even enhance them.

Many countries have experienced unsustainable water resources development and management as a result of silo-like, sectoral policy making and planning that takes little or no consideration of water uses beyond the interests and jurisdiction of individual sectors. Recognition of the lack of sustainability of this situation has resulted in an explosion of interest in more holistic approaches to developing and managing water resources, most notably Integrated Water Resources Management (IWRM). Combining an ecosystem services approach with IWRM would help achieve social equity, economic efficiency and ecosystem sustainability (FIGURE 4).

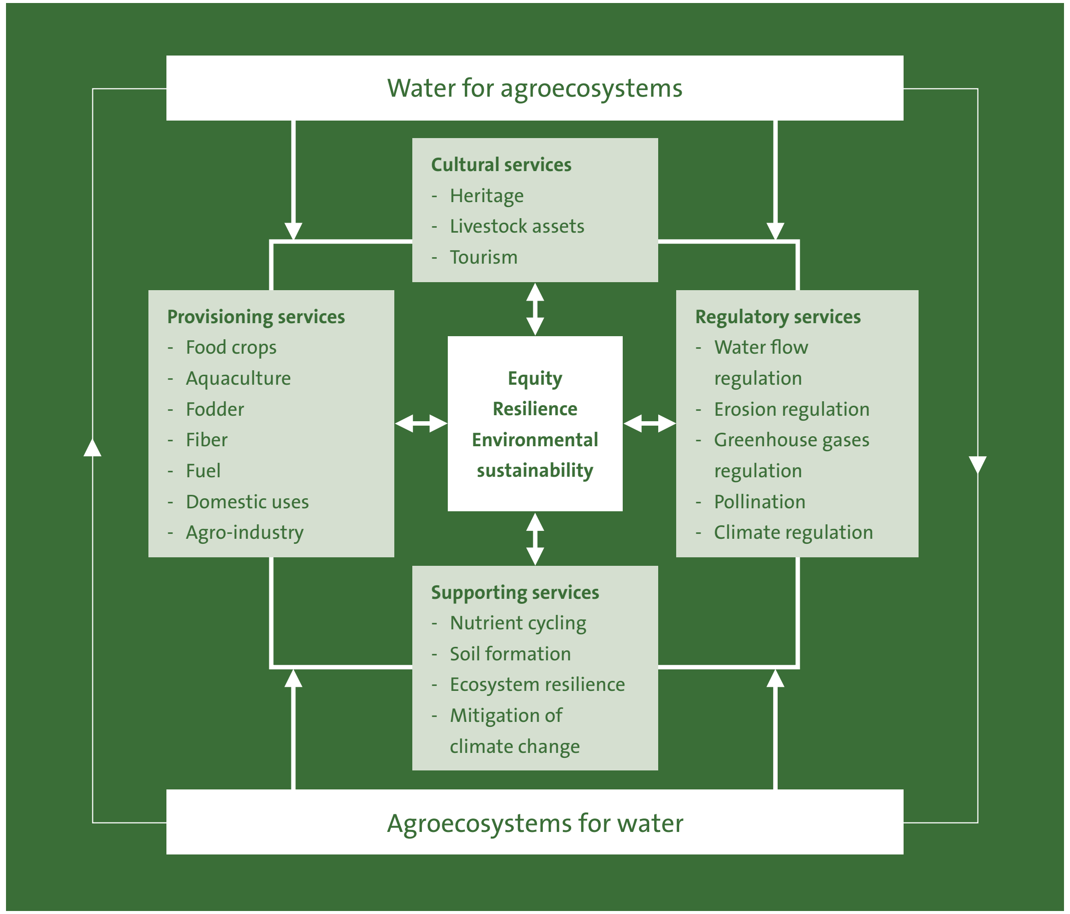


FIGURE 4: Water management for agroecosystems will enhance more ecosystem services and lead to environmental sustainability, equity and resilience to shocks.

Other important tools in managing water for ecosystems and ecosystems for water include: economic valuation and cost-benefit analysis of ecosystem services, assessment of environmental flows, risk and vulnerability assessment, strategic and environmental impact assessment and probability-based modeling. It is important to consider the different impacts on men and women, particularly when carrying out a cost-benefit analysis of ecosystem services.

Recommendations

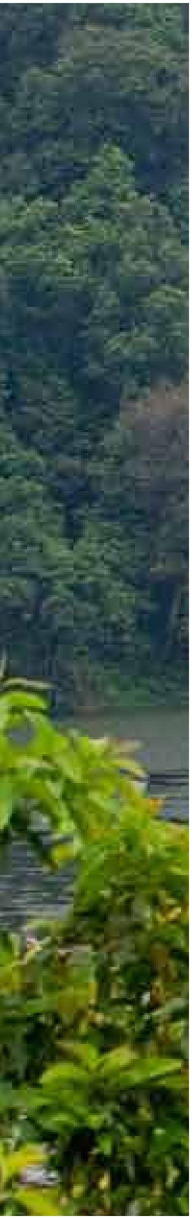
In the realm of water management, there is scope for actions at different levels and scales: national, river basin, catchment and local.

- **At the national/state scale:** When putting into place frameworks for allocating water resources and planning land and water development, ensure that various ecosystem services, including regulatory and supporting services, are valued in order to avoid causing unintended trade-offs—particularly trade-offs that are ultimately detrimental to water and food security. Greater investment is also needed in assessing, monitoring and protecting environmental flows. These requirements need to be recognized in legal frameworks, policies and regulations.

- **At the river basin scale:** Water accounting—to see where and how water resources in a basin are being used—can reveal opportunities for real water savings, free up water for ecosystems and ensure that initiatives to improve water efficiency in agriculture, which reduce the amount of water returning to the system, do not end up hurting downstream users. Environmental flows need to be assessed at the river basin level and maintained for important ecosystems (Box 3). In addition, resource users—farmers, pastoralists, environmentalists, fishers and domestic users—need to be brought together in a common management arrangement to resolve conflicts between competing users and promote greater social and gender equity.

- **At the subbasin and watershed scale:** Ensuring that water management recognizes the multiple ecosystem services of agroecosystems can enhance services and improve sustainability. Strategic tree cover interventions can help regulate flows and reduce erosion. Conjunctive use of groundwater and surface water and more attention to the management of rainwater can reveal synergies, improve equity and productivity per drop, particularly in the world's poorest areas.

- **At the community/farm-level:** There are many water management technologies and practices that could increase the productivity and resilience of agroecosystems while enhancing other ecosystem services, such as rainwater harvesting, soil management to facilitate rainfall infiltration and conserve nutrients, drip irrigation, cultivation of water-conserving resilient multipurpose (e.g., food/feed) tree-crop mixtures, maintaining year-round soil cover, as well as hedges, tree rows and other vegetation corridors. But because these practices often involve higher risk or lower returns, farmers need incentive schemes in order to adopt these schemes, such as payment for ecosystem services (FAO 2007). Even in the case of practices that could result in beneficial economic returns, people need access to information, appropriate technologies and finances to adopt and adapt to these practices. Lastly, there are social constraints that need to be overcome, for instance, women are often excluded from stakeholder's consultations and user groups who are involved in water management.



BOX 3

Environmental flows

The concept of environmental flows—the quantity, quality and timing of water flows necessary to sustain ecosystem services, in particular, those related to downstream wetlands and aquatic habitats and the human livelihoods and well-being that depend on them (adapted from eFlowNet 2010)—has achieved widespread recognition but it has been a challenge for many countries to implement. Most effort has been invested at the project specific level, e.g., individual large dam projects. Few countries have determined the required environmental flows at the river basin level and included provision for such flows in national water allocation frameworks.

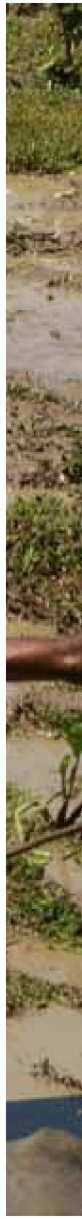
Environmental flows are seasonal and basin-specific. The idea is that consumptive water use should be set at levels that do not undermine ecosystem resilience and productivity. Hence, it is critically important that in water resources planning a certain volume of water is reserved for the maintenance of freshwater ecosystem functions and the services they provide to people, also referred to as Environmental Water Requirements (EWR). Hence, environmental flows could be seen as 'environmental demand'—similar to crop water requirements and industrial or domestic water demand (Smakhtin & Eriyagama 2008).

It is not only the amount of water, but also the timing that is important. High flows of different frequency are important for channel maintenance and wetlands, while low flows of different magnitudes are important for algae control, fish spawning and maintaining diversity of aquatic habitats. However, maintaining the full spectrum of naturally occurring flows in a river is normally impossible due to water resources development and catchment land-use changes. Planned environmental flows can, therefore, be seen as a compromise between natural river flow regimes and the control of water needed to harness it for human use—e.g., hydropower, irrigation, flood control.

6

Agriculture, aquaculture and livestock: from production systems to agroecosystems

The success of modern agriculture is based on provisioning ecosystem services, particularly food, fuel and fiber. However, the expansion of these marketable ecosystem services has resulted in the degradation of other valuable and essential ecosystem services such as climate regulation, water regulation, biodiversity, pollination and soil erosion protection. Widening the focus on food production to include other ecosystems services—particularly those that underlie sustainability and resilience—is our best hope for feeding a growing population and improving rural livelihoods, even in the face of challenges such as climate change.



Agriculture and ecosystem services are interrelated in at least three ways: (1) agroecosystems generate ecosystem benefits such as soil retention, food production and cultural services; (2) agroecosystems receive beneficial ecosystem services, such as pollination and soil formation from non-agricultural ecosystems; and (3) ecosystem services from non-agricultural systems may be impacted by agricultural practices.

Taking into account these interconnections and looking at agricultural production systems—even intensive agricultural production systems—as agroecosystems, reveals opportunities to reduce losses and increase resource use to produce more food per unit of land and water and to increase a range of ecosystem services (Figure 5). The agroecosystem approach can improve food security and nutrition by diversifying food sources while also improving sustainability. For example, rice fields in Vietnam are used to grow rice (increase food security); reduce erosion and buffer water quantities (both regulatory services); retain nutrients (supporting services); and at the same time diversifying production by allowing for fish and other aquatic animals in the rice fields and in ponds interspersed with the fields for domestic and animal use. Similarly, multipurpose trees help increase infiltration and reduce runoff (regulatory services) and can be used in agricultural landscapes to connect forest habitats; bringing insects for pollination and soil organisms closer to fields; cycle nutrients and carbon (supporting services); and also diversify production by providing fuelwood and timber in addition to fodder and fruit (increasing food security).

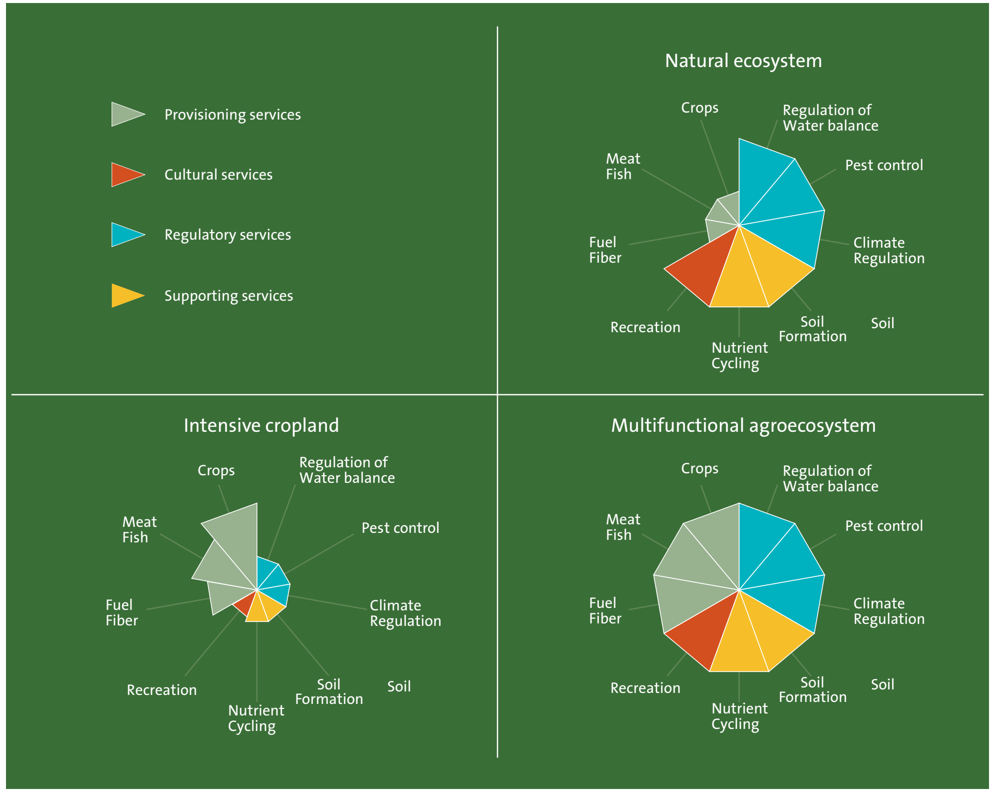


FIGURE 5: The balance (or imbalance) of ecosystem services in natural ecosystems, intensive monocropped systems and in well-balanced multifunctional agroecosystems.

The following sections look at opportunities that can be found in particular food production systems.

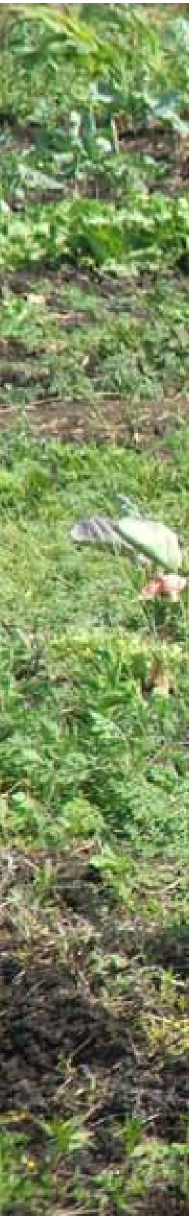
Crops

Agriculture is faced with significant challenges in relation to water use and availability (de Fraiture & Wichelns 2010). There are solutions that will enable us to increase production, make more efficient use of water resources and enhance ecosystem services (Gordon et al. 2010). This change in thinking will result in systems that are more sustainably productive and resilient in the face of climate change. To support this, it is helpful to look at agriculture as a continuum between fully rain-dependent and entirely irrigated systems (Rockström et al. 2010).

The Comprehensive Assessment of Water Management in Agriculture (CA) argues that to meet future food demand and reduce poverty we should focus on increasing productivity in the least productive rainfed areas. Currently, some 95% of agriculture in sub-Saharan Africa and 60% in India is under rainfed cultivation (CA 2007). Agricultural productivity could be increased here by intensification without expanding the land area and water use. Productivity from rainfed agriculture remains low due to limited water availability at critical growing periods, limited soil nutrient availability and occurrence of pests and diseases. Several of these limiting factors are related to degradation of ecosystem services—degradation that could be halted or even reversed through incentives for better land and water management practices. In rainfed agriculture, emphasis must be on securing water to bridge dry spells and improving soil management to increase nutrient availability and the water holding capacity of the soil profile. A small change in tree cover can have a large impact on infiltration and catchment hydrology (Carroll et al. 2004).

In existing irrigation systems, the focus needs to be on implementing management strategies that reduce costs and increase water productivity, for example, by promoting greater integration with other methods of food production, particularly livestock and fisheries. Redesigning irrigation schemes to on-demand systems, where water is used to supplement rainwater and soil water, may allow a much higher agricultural production with the same amount of water, as is the case in Syria where wheat yields were doubled by adding 150 millimeters (mm) of irrigation water to 300 mm rainwater (Oweis & Hachum 2006).

Further improvements in the productivity of agroecosystems can be achieved using the following guiding principles (Molden et al. 2007; Hajjar et al. 2008; Zomer et al. 2009; Garrity et al. 2010):



- **Promote diversity within the cropping system:** Optimizing the diversity within cropping systems (crop biodiversity, soil biodiversity and pollinators) can increase the adaptive capacity to buffer against fluctuations in water availability and thus enhance the resilience of rural livelihoods. Integration of trees in crop fields to fix nitrogen, tighten nutrient, water and carbon cycles, and produce fruit, fodder, fuelwood and timber.

- **Promote diversity in landscapes:** Large monocropped areas can be developed into landscapes with higher levels of biodiversity by identifying and linking natural habitat patches. Habitat integrity and connectivity can be maintained by incorporating hedgerows, multipurpose trees and corridors of natural vegetation interconnecting parcels of agricultural land. This creates landscapes that are more resilient and better able to mitigate environmental impacts, as hedgerows and buffer strips also reduce runoff and erosion, and help protect watercourses and field crops.

- **Choose the right infrastructure and operation:** Infrastructure planning and operation should widen the focus from delivering water to field crops to providing water for multiple uses, including both domestic and productive uses.

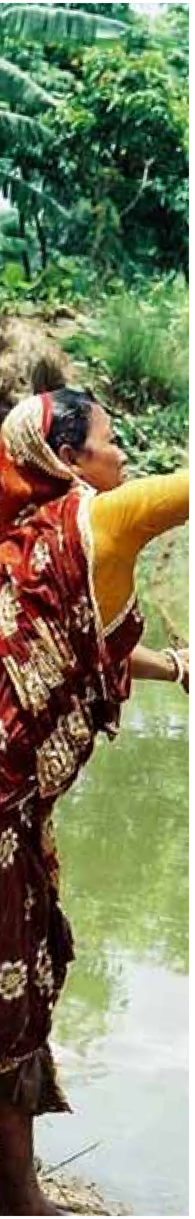
- **Mobilize social organization and collective action:** Engaging local communities in irrigation system and water resources management is critical to manage water sustainably and meet the needs of different members of society, particularly those of marginalized groups including women.

- **Develop institutions for integrated water resources management:** Up to now, relatively more effort has been placed on building institutions to manage irrigation delivery than to the overall management of water and natural resources. But institutions must be developed and supported to maintain healthy multifunctional agroecosystems and ensure equity of access, use and control over resources. At a larger scale, institutional arrangements need to incorporate means to deal with both on-site and off-site effects.

Fish

Fisheries and aquaculture are major sources of protein in many developing countries, providing more than 2.9 billion people with at least 15% of their average per capita animal protein intake, according to 2006 figures (FAO 2009a). Small-scale inland fisheries in developing countries provide 33% of the world's small-scale fish catch and employment for more than 60 million people, of which 33 million are women (UNEP 2010). Most of this fish is used for home consumption.

Both aquaculture development and fisheries depend on the appropriation of various environmental goods and services from aquatic ecosystems including clean and oxygenated water for physical support and respiration, seed, feed and detritus inputs, waste removal, nutrient assimilation and carbon sequestration. Capture fisheries



and aquaculture are threatened by habitat degradation, pollution, invasive species, landscape fragmentation, disruption of river flows by dams and overexploitation of upstream water resources (UNEP 2010). These pressures, along with the increased demand due to population growth, have caused a severe decline in the quantity of fish and other aquatic species, particularly in inland fisheries. This decline particularly affects poor rural men, women and children, who depend on fish as an important source of food and nutrition.

Evaluation of the full range of provisioning ecosystem services from aquatic ecosystems, not only fish, is vital if the true value of such 'aqua-ecosystems' in the livelihoods of people and local and national economies is to be accounted for and safeguarded. Capture fisheries are the most frequently cited benefit of aquatic ecosystems, but these systems also provide biodiversity, cultural services and aesthetic values. Continued provision of fish stocks and flows of ecosystem services may actually benefit more people and make significant contributions to their well-being and resilience (Brummett et al. 2010).

For capture fisheries, in addition to managing sustainable fishing practices, the focus should be on maintaining the connectivity of migratory routes and habitats required for different life cycle stages such as breeding and feeding. In aquatic and humid agroecosystems, ecologically sustainable water management often involves multiple uses of water for the whole range of ecosystem services. Some good examples are the integration of aquaculture into various agroecosystems such as livestock-aquaculture integration, rice-fish culture, aquaculture in irrigation reservoirs and water management schemes, and wastewater-fed aquaculture (van der Zijpp et al. 2007).

Livestock

Livestock products provide one-third of the human protein intake, but also consume almost one-third of the water used in agriculture globally (Herrero et al. 2009). Livestock grazing is also the single largest user of land. Most of the world's animal production comes from rainfed mixed crop-livestock systems in developing countries and from intensive industrialized production in developed countries (Herrero et al. 2010). The growing demand for animal products can be an opportunity for poor livestock keepers, both men and women, or it can drive them deeper into poverty as pressure on land and water resources increases competition and leads to ecosystem degradation.

Despite the perception of livestock being a major cause of environmental degradation, evidence shows that historically the world's traditional pastoral lands are not the primary areas for desertification, unsustainable water use and greenhouse gas emissions. In these areas, grazing animals capture the benefits of sparsely distributed rainfall by grazing on rainfed pastures (Bindraban et al. 2010). Due to their large area, rangelands as a whole can also be considered to be a global carbon sink of a roughly similar size to forests (Herrero et al. 2009).

However, in recent decades, the expansion of cultivation along with the establishment of international boundaries and barriers across traditional migratory routes have diminished herd mobility and forced herders to adopt more sedentary livelihood strategies. The result has been an increase in severe land and water degradation and aggravated poverty, poor health and food insecurity. Unintentional trade-offs associated with livestock production systems include environmental issues such as impacts on water scarcity, nutrient cycling, climate change and land degradation (Herrero et al. 2009).

Opportunities exist for the sustainable management of livestock systems that maintain ecosystem services. These include policies that enable the management of climate variability such as early warning and response systems, improved markets, fodder reserves and insurance schemes to cover for loss of livestock (World Bank 2009). Others deal with changing the incentive system for keeping large herds, such as payment for environmental services. Measures to improve animal health, such as access to veterinary services and a continuous supply of adequate quality water, also make it possible for livestock keepers to derive more food and income per animal (World Bank 2009). Interventions also need to take into account women's roles in livestock production systems. Livestock often provide the main sources of income for women, particularly in mixed crop-livestock systems.

Innovative approaches aim at improving water use in livestock (or 'Livestock Water Productivity') (Peden et al. 2009; Herrero et al. 2010; Descheemaeker et al. 2010):

- **Feed related strategies** includes using crop residues and other waste products for feed, increasing feed water productivity by altering feed crop choice, implementing more sustainable grazing management practices and farm-level integration of trees within crop-livestock systems to improve year-round availability of fodder and biomass for use as fertilizer and fuel.

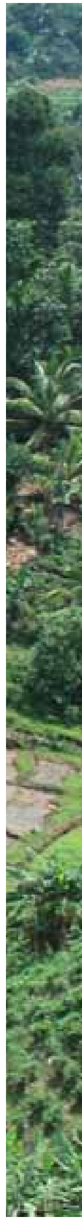
- **Water management strategies** includes water conservation, strategic placement of watering points (to encourage more complete and uniform grazing and enable animals to reach otherwise inaccessible feed sources) and integration of livestock production into irrigation schemes.

- **Animal management strategies** includes appropriate animal husbandry and improving animal health, supported by awareness raising among livestock keepers, so that feed can be used more effectively and herders are able to get the same benefit from a smaller number of animals.

7 Key recommendations

By providing more insight into the links between ecosystems, water and food, a way forward is suggested that places ecosystems at the heart of food security efforts. Opportunities exist to increase food production in ways that make optimal and sustainable use of water and other resources (for further information, see *Ecosystems for water and food security*[1]).

[1] The full report Ecosystems for water and food security can be downloaded at www.unep.org/ecosystemmanagement or www.iwmi.org/ecosystems



The recent world food crises demonstrated the vulnerability of our food supply and the need to improve its sustainability and resilience. We know that one of the main factors limiting future food production will be water. Integrated water resources management can contribute to long-term food security by providing water for agroecosystems and for non-agricultural ecosystems. Thus, more resilient ecosystems can support a wider range of ecosystem services, including water management functions that are crucial for stable food security, and become more diverse and more productive.

This requires changes, as detailed below, in how we approach ecosystems, water resources management and food security.

- **Value ecosystem services** from agroecosystems and non-agricultural ecosystems, so that these can be used to understand incentives and trade-offs.

- **Manage agriculture as a continuum of agroecosystems** that not only produce food, but also deliver a whole range of other ecosystem services necessary for long-term food security, in a larger and diverse, tree-rich landscape.

- **Collaborate between sectors,** as multiple services from agroecosystems require support from authorities and experts in, for instance, agriculture, environment, water, aquaculture, forestry, fisheries, livestock and wildlife management at local, basin, national and international scales. This may include specific incentives to users—farmers, fishers, livestock herders—to maintain and improve ecosystem services.

- **Manage all sources of rainwater and runoff for multifunctional agroecosystems** at river basin level to support the widest range of ecosystem services. With higher water productivity in terms of ecosystem services (water for agroecosystems), ecosystems will in turn be more efficient in their regulating and supporting water services agroecosystems for water).

- **Use adaptive Integrated Water Resources Management** supported by capable and empowered institutions to provide water for non-agricultural ecosystems (water for nature/environmental flows) and agroecosystems (water for food).

Specific opportunities to enhance food security and increase water productivity include:

- **Strategic placement of multipurpose trees** in agricultural landscapes to tighten water, nutrient and carbon cycles that sustain soil and water productivity, thereby reducing pressure on the remaining forest resources.

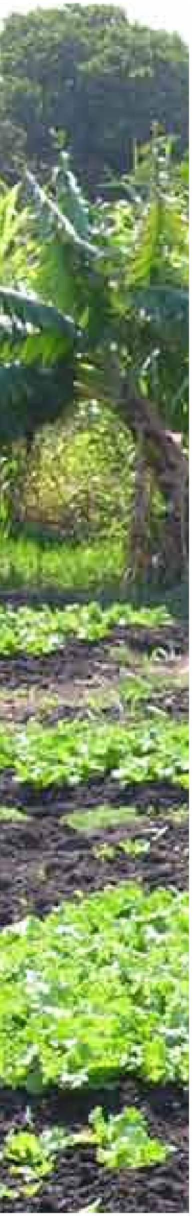
- **In dryland agroecosystems** with locally adapted cultivars, holistic utilization of water and nutrients, provisions for herds and integrated tree-crop-livestock management that are all crucial to guarantee ecosystem services in the long term.

- **In wetland ecosystems** by developing synergies with fisheries, aquaculture, livestock grazing, and horticulture and strategic enhancement of tree cover without compromising the water regulating functions and other ecosystem services of the wider catchment, including groundwater.

- **In crop systems,** where the highest potential is in increasing rainfed crop production, yield increases could be obtained over vast cropland areas with targeted surface water and groundwater management to bridge dry spells, careful nutrient management, innovative field practices and adapted cultivars. More ecosystem services could be provided by crop-tree-agroecosystems, if (a) diversity within the cropping system as well as in landscapes is promoted, (b) habitat integrity and connectivity are maintained, (c) the right infrastructure is selected, and (d) effective supporting institutions are in place for water management and collective action.

- **In aquaculture and fisheries** by providing healthy aquatic ecosystems with clean and oxygenated water for physical support and respiration, seed and feed. If managed well, such aquatic ecosystems need, and in return will also provide, regulation of detritus, waste, nutrient cycling and carbon sequestration. In capture fisheries, maintaining migratory routes and breeding habitats as well as sustainable fishing practices are important. More ecosystem services can be provided in multipurpose aquatic ecosystems such as livestock-aquaculture integration, rice-fish culture, aquaculture in irrigation and water management systems, and wastewater-fed aquaculture.

- **In livestock systems** animal management strategies to improve animal health and survival can reduce herd sizes, while feeding strategies such as the use of crop residues and other waste products, tree fodder, proper selection of fodder crops and implementing grazing management practices can increase livestock water productivity, while water quantity and quality can be conserved by, for instance, water point management. More ecosystem services can be provided in, for instance, mixed crop-livestock systems with multipurpose crops and by integrating livestock in irrigation systems.



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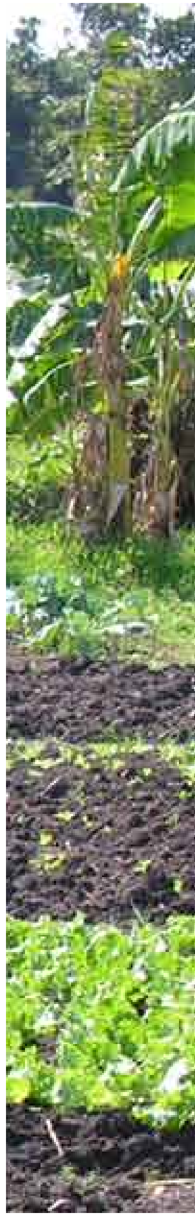

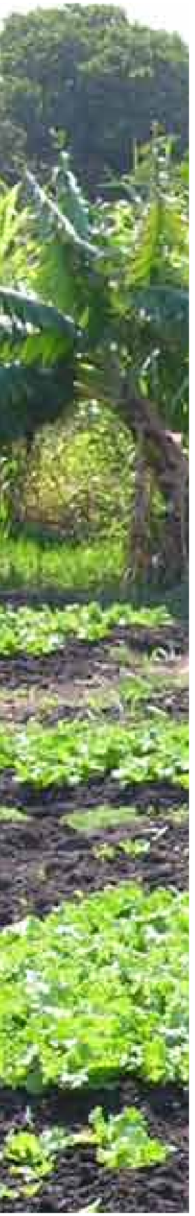

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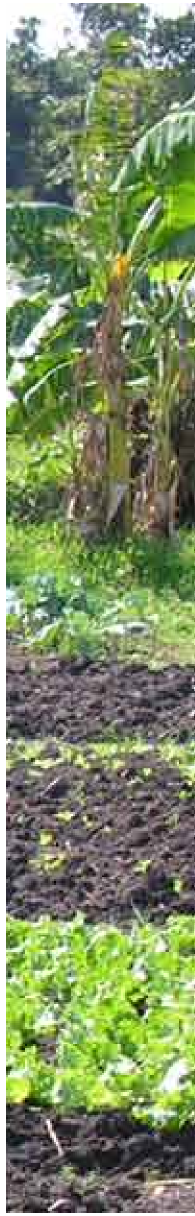

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