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137

Wetlands, Agriculture and Poverty Reduction

Matthew McCartney, Lisa-Maria Rebelo, Sonali Senaratna Sellamuttu and Sanjiv de Silva

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Cover photograph shows the cultivation of a wetland in Mozambique (photo credit: Matthew McCartney).

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Contents

Summary

Wetlands contribute in diverse ways to the livelihoods of millions of people. They are often inextricably linked to agricultural production systems. In many places, growing population, in conjunction with efforts to increase food security, is escalating pressure to expand agriculture within wetlands. The environmental impact of wetland agriculture can have profound social and economic repercussions for people dependent on ecosystem services other than those provided directly by agriculture. If wetlands are not used sustainably, the functions which support agriculture, as well as other food security and ecosystem services, including water-related services, are undermined. Currently, the basis for making decisions on the extent to which, and how, wetlands can be sustainably used for agriculture is weak. There is a dearth of knowledge on the best agricultural practices to be applied within different types of wetlands and a lack of understanding on how to establish appropriate management arrangements that will adequately safeguard important ecosystem services. Often, wetland policies are underpinned by a conservationist perspective that regards agriculture simply as a threat and disregards its important contribution to livelihoods. This report synthesizes findings from multidisciplinary studies conducted into sustainable wetland agriculture by IWMI and partners in Africa and Asia. It highlights the value of wetland agriculture for poverty reduction as well as the need for more systematic planning that takes into account trade-offs in the multiple services that wetlands provide.

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Introduction

Wetlands can be considered as sinks into which surface water or groundwater flows from a surrounding catchment. Within landscapes they are "natural harvesters" of rainwater and, by definition, sites where water occurs at or close to the ground surface. Throughout history they have played an important role in human development and many great civilizations (e.g., the Maya, Inca and Aztec in Latin America, the Khmer in Asia, the Marsh Arabs in Mesopotamia and those of the Nile and Niger in Africa) depended on them.

Agriculture is a commonly associated feature of wetlands throughout the world, with millions of hectares of wetland of various types supporting a wide range of activities. Conversely, many wetlands are threatened by these same agricultural practices, which modify the hydrological and other natural regimes on which they depend, and hence, their ecological character and the other benefits they provide. As the human population increases and further influences the management of water and other natural resources, the value of wetlands to society increases, but so also do the pressures on them.

Wetland agriculture is important for poverty reduction and food security in many developing countries (Frenken and Mharapara 2002). However, there is little recognition of its current extent, its value to poor communities or its future potential. A major constraint is lack of knowledge by government planners, managers of natural resources and local communities of the diverse benefits they provide and how they can be utilized for agriculture in a sustainable manner (McCartney et al. 2005). Frequently, the threats of drainage and overexploitation of resources are perceived as key issues in determining wetland utilization for agriculture, but with limited and, often, misconceived, understanding of actual impacts and trade-offs with other ecosystem services (Bullock and McCartney 1995).

There is little consensus about what constitutes "wise use" of wetlands and there is often tension between conservation and development approaches that is rarely reconciled. Frequently, wetland policies are driven by a conservation agenda that actively discourages or ignores wetland agriculture. At best, this means that wetland farmers are deprived of extension services that could help them better manage their wetland resources (van de Giesen and Andreini 1997). At worst, it means that, often based on sparse or nonexistent scientific evidence, communities are forced from wetlands with disastrous consequences. For example, as recently as 2007, pastoralists were forcibly evicted from wetlands in Tanzania in line with a government policy intended to curb environmental degradation. This resulted in thousands of cattle dying and great hardship for many people (The East African 2007).

This report synthesizes research conducted by IWMI and partners, as well as other researchers, into the wetland-agriculture nexus. It is not a comprehensive overview of all facets of wetland-agriculture, but rather focuses on those aspects in which IWMI has been involved in the past, primarily in Africa and Asia. The report also touches on wetlands in the broader context of food security and livelihoods and the value of these provisioning services, as well as other ecosystem services (in particular water-related services), in the context of poverty reduction. The report highlights the importance of wetland agriculture - an ecosystem service too often overlooked and undervalued - and emphasizes the dichotomy of wetlands as an important agricultural resource whilst simultaneously threatened by inappropriate agricultural practices.

Wetland Extent and Distribution

There is great uncertainty about the number and extent of wetlands globally (Rebelo et al. 2009a). This uncertainty is due, in part, to differences in definitions (i.e., what actually constitutes a wetland)[1] and, in part, to differences in methods of mapping and approaches to inventorying. However, there is scientific consensus that wetlands cover at least 6% of the Earth's surface and that even the most recent estimates of wetland extent are underestimates; significant gaps remain in some regions and for various wetland types (Finlayson and D'Cruz 2005).

Two recent global estimates are presented in Table 1. The first, derived from multiple geospatial data sets, produced a global estimate of 917 million hectares (Mha) (Lehner and Döll 2004) whilst the second, derived from national inventories, produced an estimate of 1,280 Mha globally (Finlayson et al. 1999). Accurate information on the distribution and extent of wetland ecosystems both regionally and globally is clearly an area which requires further work. However, taking these data as the best currently available, a minimum of 131 Mha of wetlands occur in Africa, and 286 Mha in Asia (Figure 1). While only a small proportion of wetlands may be suitable for agriculture, to put these figures in context they compare to an estimated global irrigated area of about 277 Mha of which approximately 194 Mha are in Asia and only 12 Mha are in Africa (FAO 2005).

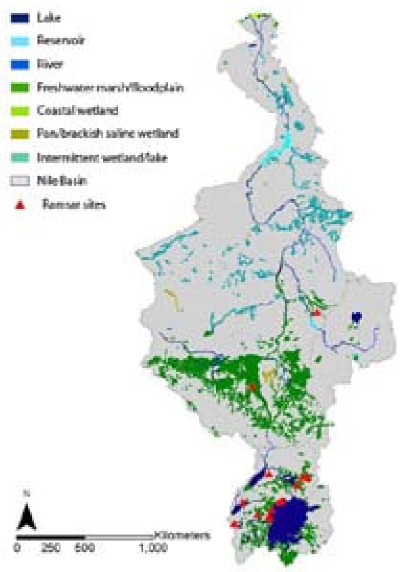
TABLE 1. Estimates of global wetland area (Mha with percentage area in parentheses) for each of the six geopolitical regions used by the Ramsar Convention on Wetlands.

Region	Global lakes and wetlands database (Lehner and Döll 2004) Mha (% area)	Global review of wetland resources (Finlayson et al. 1999) Mha (% area)
Africa	131 (14)	125 (10)
Asia	286 (32)	204 (16)
Europe	26 (3)	258 (20)
Neotropics	159 (17)	415 (32)
North America	287 (31)	242 (19)
Oceania	28 (3)	36 (3)
Total	917	1,280

[1]Because wetlands represent a continuum between aquatic and terrestrial environments their formal definition is difficult and has long been a source of controversy. Currently, there are many definitions of wetlands all of which have strengths and weaknesses. One widely used, internationally accepted, definition is that of the Ramsar Convention: the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (UNESCO 1971). This has a very broad definition covering a wide range of ecosystems: "*Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters*." A number of alternative definitions are provided in Maltby 2009.

FIGURE 1. Spatial distribution of wetlands and lakes across Africa and Asia (*Source*: Lehner and Döll 2004).

In the Nile Basin wetlands are estimated to cover 18.3 Mha (i.e., about 5% of the basin; Figure 2), although this is likely an underestimate. They play a vital role in the livelihoods of many millions of people. In addition, the entire wetland network in Uganda is thought to contribute to the hydrological regime of the Nile Basin and the ecohydrology of the region (Bugenyi and Balirwa 1998). Other examples of the multiple contributions that wetlands make to livelihoods are those associated with the Inner Niger Delta in Mali, Lake Chilwa in Malawi and the Tonle Sap in Cambodia (Boxes 1, 2 and 3). These are famous large wetlands where contributions to livelihoods have been well documented. However, in Africa and Asia many thousands of lesser-known, usually small, wetlands make similar significant, but often unrecognized, contributions to the welfare of people. In many cases the economic and social values are disproportionate to the areal extent of wetlands.



Country	Wetland area (ha)
Eritrea	130
Chad	5,110
Burundi	11,040
DRC	23,050
Kenya	57,270
Ethiopia	208,030
Rwanda	331,250
Egypt	497,210
Tanzania	1,247,260
Uganda	1,787,200
Sudan	14,181,930
Total	18,349,480

FIGURE 2. Spatial distribution and areal extent of wetlands within the Nile Basin. Data are derived from the Global Lakes and Wetlands Database (*Source*: Lehner and Döll 2004), and country-based Africover data sets (*Source*: Di Gregorio 2002).

Box 1. Importance of the Inner Niger Delta to livelihoods in Mali (*Source*: Zwarts et al. 2005).

The Inner Niger Delta, also known as the Macina, is a large area of floodplain and lakes located between the bifurcated Niger River and its tributary, the Bani, in the semiarid area of central Mali. During the rainy season (July to October) the delta covers a maximum area of approximately 20,000 km^2, contracting to a minimum of about 3,900 km^2 during the dry season. Approximately 1 million people live within the delta with livelihoods largely supported by fishing, livestock breeding and cultivation. Within the delta, rice, millet, maize, and wheat are cultivated in the rich floodplain soils. Farming varies from basic subsistence to larger, irrigated projects. Yields for nonirrigated crops grown on the floodplain are highly dependent on flood levels. For the years 1987 to 2003 rice production varied from 10,600 to 115,700 tonnes per year (ty^{-1}). Livestock are numerous, with as many as 2 and 3 million head of cattle and sheep, respectively, making these some of the highest-density livestock herds in Africa. Grazing varies seasonally with pastoralists moving herds to the uplands during the rainy season when water levels rise and on to the floodplain as the water recedes. It is estimated that 300,000 people living in the delta depend on fisheries for their livelihood. Annual fish production is uncertain and also very variable, but is estimated to be between 40,000 and 80,000 ty^{-1}. In recent years, upstream dams and irrigation schemes have affected both the magnitude and timing of the annual flood. It has been estimated that average annual rice production has been reduced by a total of 15% (13,200 tonnes) and fish trade has been reduced by 18% (4,175 tonnes) as a consequence of these changes.

Livestock watering (*Photo credit*: Sanjiv de Silva).

Harvested thatch (*Photo credit*: Sanjiv de Silva).

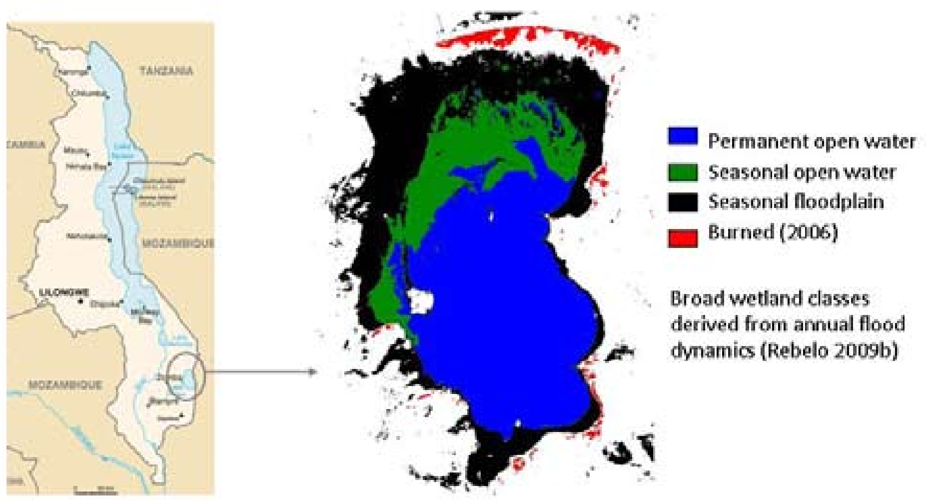
Wetlands and Human Well-being

The value of wetlands for people arises from the interaction of the ecological functions they perform with human society (Figure 3). Those in Africa and Asia play a particularly vital role in directly supporting and sustaining livelihoods. They do this through the provision of a range of "ecosystem services" which bring both physical and nonphysical benefits to people.

Ecosystem Services

Ecosystem services as defined by the Millennium Ecosystem Assessment (MEA 2005; Figure 4) are "*the benefits people obtain from ecosystems*." Different wetlands perform different functions and hence provide different ecosystem services depending on the interactions between their

Box 2. Importance of the Lake Chilwa wetland to livelihoods in Malawi (*Source*: Rebelo et al. 2009b).



Irrigated rice | Floodplain maize | Fishing in wetland | Livestock grazing on floodplain | Ramsar notice

The Lake Chilwa wetland covers an area of 2,248 km^2 and consists of a shallow open water lake surrounded by reed swamp, marsh and floodplain grassland. It is one of the most important wetlands in Malawi. The wetland is an important source of livelihood for over a million people who subsist on agriculture, fishing and birds. With approximately 162 persons per km^2 (pkm^{-2}) the Lake Chilwa catchment has one of the highest population densities in the country; the national average is 104 pkm^{-2}. In terms of fisheries, Lake Chilwa is one of the most productive lakes in Africa typically providing 20% and in some years up to 43% of the country's total fish catch (Jamu et al. 2006). Fishing takes place in the area of permanent open water year-round. The floodplain is also used for fishing during the wet season, and subsequently for small-scale rice growing as the flood levels recede. During the dry season this area is predominantly used for grazing and the cultivation of vegetables. Several large-scale irrigation schemes were established within the wetland in the 1970s growing high-yielding varieties of rice. Production from these constitutes 50% of all the rice grown in Malawi. The economic value of the wetland is estimated at $21[2] million per year ($My^{-1}$) (Schuyt and Brander 2004).

physical, biological and chemical components, and their surrounding catchments.

Water is the fundamental component that supports the functioning and production of all wetland ecosystem services, of which four broad classes have been identified (MEA 2005). Typically, the physical benefits from wetlands include "provisioning services" such as domestic water supply, fisheries, livestock grazing, cultivation, grass for thatching, and wild plants for food, crafts and medicinal use. Other ecosystem services are often not explicitly recognized by communities, but

[2] In this report $=US$.

Box 3. Importance of the Tonle Sap wetland to livelihoods in Cambodia (*Sources*: Baran 2005; Matsui et al. 2006; Senaratna Sellamuttu et al. 2008a).

The Tonle Sap Great Lake area in Cambodia is the largest freshwater body in Southeast Asia, comprising the Tonle Sap Lake, as well as the adjacent floodplain and the rivers and tributaries that feed the lake. This unique wetland ecosystem is home to nearly 3 million people, most of whom derive their livelihoods directly from its natural resources (Resurreccion 2008). The Tonle Sap Lake is connected to the Mekong River through the Tonle Sap River and is therefore an integral part of the Mekong River System. The Lake expands and shrinks dramatically with the seasons, ranging from approximately 2,700 km^2 in the dry season, to 16,000 km^2 in the wet season. This is because the Tonle Sap River drains into the Mekong River during the dry season but in the wet season the flow reverses and water flows from the Mekong into the lake.

This unique hydrological cycle influences the fisheries of the lake, which together with its seasonally flooded forests, has a high diversity of fish species. The economic significance of the fish resource from the area is significant, representing 60% of Cambodia's total inland fisheries with an average of 41,740 ty^{-1}. Paddy cultivators have also taken advantage of this flood regime with deepwater rice and recession rice being cultivated in the floodplains around the Tonle Sap Lake (Nesbit 1997). Therefore, fishing and farming are both closely associated with this wetland system. During the wet season many households engage primarily in cultivating rain-fed rice, while some subsistence fishing is carried out in the paddy fields. During the dry season the villagers cultivate recession rice in the floodplain area of the Tonle Sap and graze their livestock. In addition, in the dry season, they engage in fishing in the flooded forest and in natural ponds in the area. Fishing is one common method of diversifying livelihood activities and is considered an insurance against the risk of agricultural failures. Fisheries also play a critical role in the food security of the local people. Fish and fish products comprise 40-60% of the animal protein intake of rural Cambodians, some suggesting the actual proportion may be closer to 75% (Keskinen 2003).

(a)

(b)

(c)

(a) Growing rice in the wetland (*Photo credit:* Chu Thai Hoanh).

(b) Fishing in the wetland (*Photo credit:* Sonali Senaratna Sellamuttu).

(c) Map of the Tonle Sap (*source:* http://en.wikipedia.org/wiki/File:TonleSapMap.png; created by Matti Kummu, Helsinki University of Technology (http://users.tkk.fi/~mkummu/)).

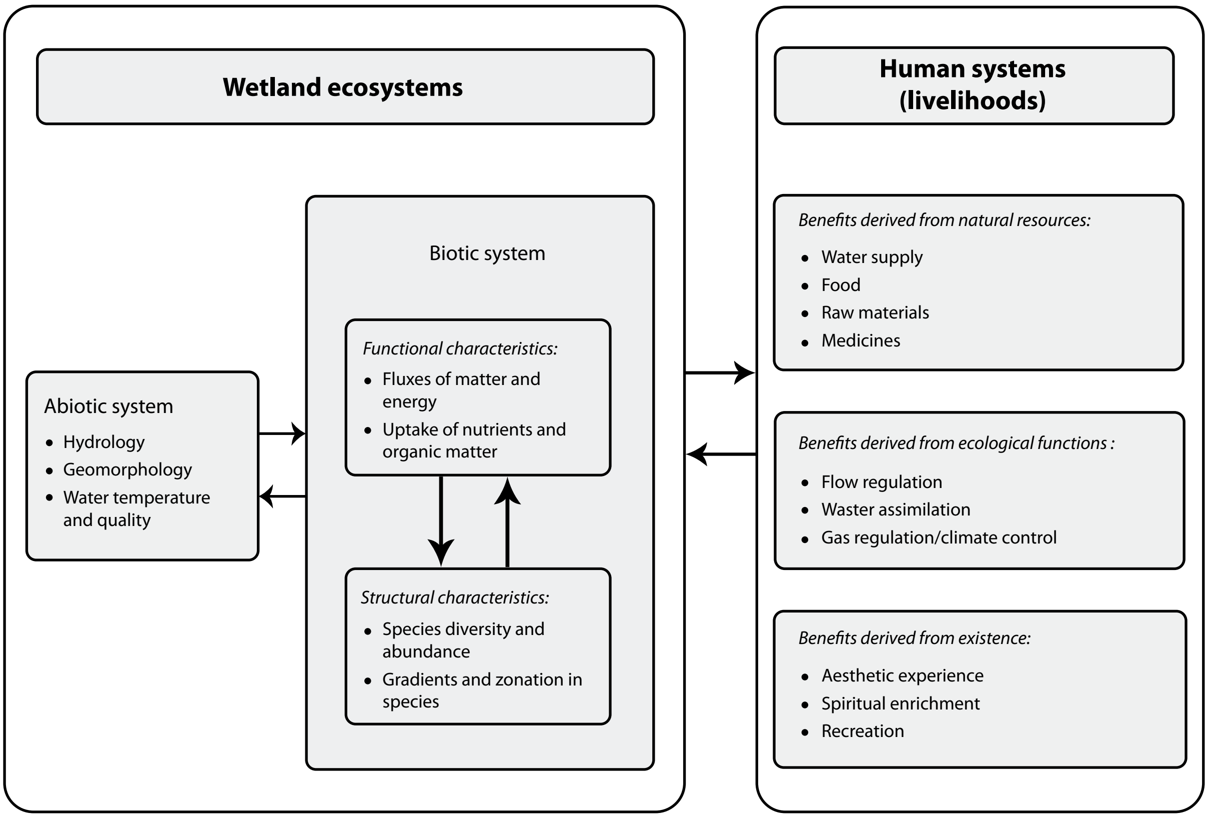


FIGURE 3. Influence of wetland ecosystems on human livelihoods (*Source*: adapted from Lorenz et al. 1997).

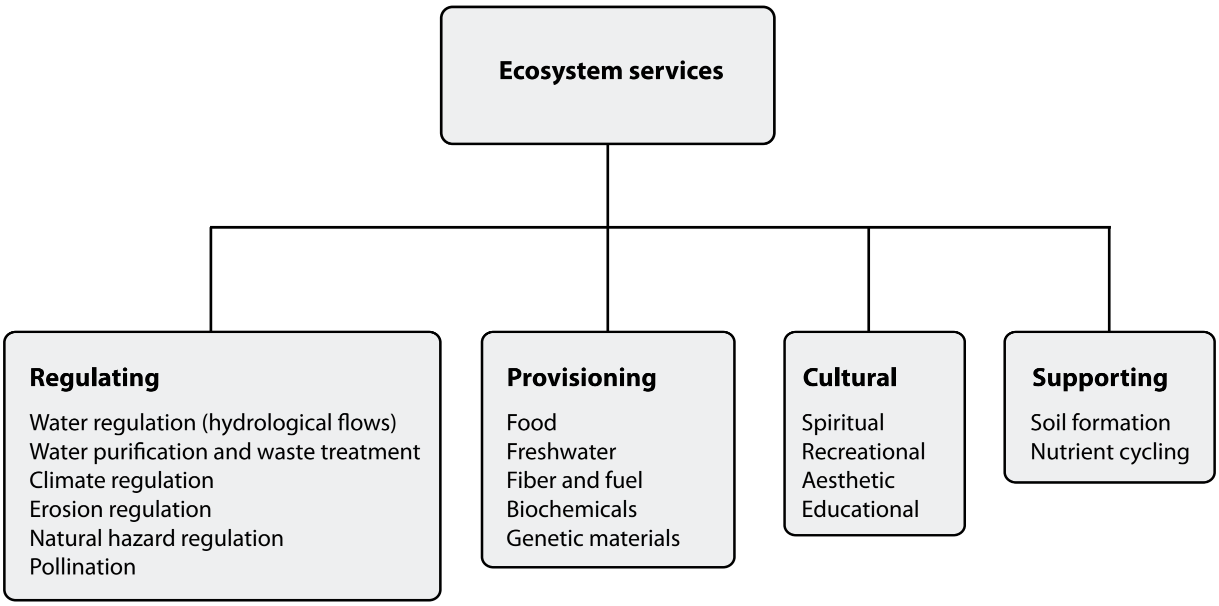


FIGURE 4. Ecosystem services provided by, or derived from, wetlands (*Source*: adapted from MEA 2005).

include a wide range of "regulating services" such as flood attenuation, maintenance of dry-season river flows, groundwater recharge, water purification, climate regulation and erosion control, as well as a range of "supporting services" such as nutrient cycling and soil formation. In addition, people also gain nonphysical benefits from "cultural services," including spiritual enrichment, cognitive development and aesthetic experience. In many instances, different types of services may be closely linked. For example, where people attach spiritual value to soils and water, wetland provisioning services may be linked to cultural services. Thus, wetlands bring a wide variety of tangible and intangible benefits to large numbers of people. The way they do so is complex and multifunctional and is directly related to the specific ecological functions and, hence, the condition of the wetland. Table 2 provides some examples of wetland ecosystem services and their importance to human society.

Wetlands' Contribution to Water Resources

Due to their role in the provision of water, regulating flows, and improving water quality, wetlands are increasingly perceived as an important component of water infrastructure (Emerton and Bos 2004). The supply of freshwater to human populations is recognized as one of the foremost natural benefits of wetlands (MEA 2005); inland wetlands provide the principal supply of freshwater for almost all human use (McCartney and Acreman 2009). Groundwater recharge is an important wetland function in some places. For example, the Hadejia-Nguru wetlands in northern Nigeria play a major role in recharging aquifers which provide domestic water supplies to approximately one million people as well as supplying water for agriculture (Hollis et al. 1993).

Wetlands play a significant role in the hydrological cycle. Their form, function and maintenance are governed to a large extent by the hydrological processes that occur both within them and their interaction in the catchment in which they are located. Patterns of flow and the chemistry of water emanating from wetlands are significantly modified by the complex interaction of these influences and many ecosystem services are attributable to the manner in which wetlands regulate water fluxes (Table 3). However, it is important to note that not all wetlands provide all of these regulatory services. The functions of a particular wetland will depend both on the type of wetland and its location within a catchment. For example, although headwater wetlands are often numerous, and their cumulative effect may be considerable, most flood-control benefits are derived from floodplain wetlands (Bullock and Acreman 2003) (Box 4). Furthermore, functions are often very dynamic. For example, the effectiveness of some wetlands in attenuating floods may be considerable at the start of the wet season, when they are relatively dry, but diminish as they become increasingly saturated (McCartney 2002).

Wetlands can be very effective at improving water quality. This is achieved through processes of sedimentation, filtration, physical and chemical immobilization, microbial interactions and uptake by vegetation (Kadlec and Knight 1996). Consequently, wetlands can be very important in the treatment of polluted water, particularly that originating from dispersed sources, as is common in agricultural landscapes. However, their capacities are variable because of dynamic production/growth and metabolic processes within them. Furthermore, if chemical loadings exceed the physiological tolerances (often unknown) of key microbial and plant species, environmental degradation is likely to occur and pollution removal is diminished (Stratford et al. 2004).

Despite research conducted to date, there remains a great deal of uncertainty about the role of different wetland types within the hydrological cycle. Hydrological processes and mechanisms occurring within many wetlands under site-specific conditions are not fully understood, and there remains a lack of numeric information relating to fluxes and water-balances in general. In many cases, regulating services attributed to wetlands are based on perception rather than on in-depth scientific understanding; in some instances, widely accepted views on the hydrological functions of certain wetlands have not withstood scientific scrutiny (Box 5). Nevertheless, because of both their

TABLE 2. Examples of different ecosystem services provided by wetlands.

Types of ecosystem service	Examples to illustrate importance
Regulating	
Flood attenuation	• The Muthurajawela marsh in Sri Lanka is estimated to have a water storage capacity of 11 Mm^3 and a retention period of more than 10 days. The flood attenuation value of the wetland is estimated to be \$5.4 My^{-1} (i.e., \$1,758 ha^{-1}) (Emerton 2005). • A flood prevention value of \$13,500 $ha^{-1}y^{-1}$ has been attributed to wetlands in the catchment of the Charles River in Massachusetts (Sather and Smith 1984).
Maintenance of dry-season flow	• The peatlands of Sarawak, East Malaysia, play a major role in providing freshwater supplies. The peatlands are an important contributor to the baseflow of the numerous streams that originate within them. It is estimated that, throughout Sarawak, 3 Mm^3 are abstracted annually from these streams (Mailvaganam 1994).
Pollution control and detoxification	• Sewage from 40% of the residents (ca 500,000) of the city of Kampala is discharged into the Nakivubo wetland (5.3 km^2). The presence of the wetland significantly improves the quality of water entering Lake Victoria, approximately 3 km from the city's main supply intake. The water purification services of the wetland are estimated to be worth about \$1 My^{-1} (Emerton 2005).
Climate regulation	• Peat deposits occupy just 3% of the world's land area but store as much carbon (400-700 gigatonnes (Gt)) as all other terrestrial biomass. If all was converted to carbon dioxide this would increase the atmospheric concentration of carbon dioxide by 200 ppm (Lloyd in prep.). • 40% of methane input to the troposphere comes from natural wetlands and rice fields (Sahagian and Melack 1996).
Provisioning	
Freshwater for drinking and domestic supply	• Based on the inclusive Ramsar definition of wetlands, over half the world's population (i.e., more than 3 billion) obtain their basic water needs from inland freshwater wetlands. The remaining 3 billion depend on groundwater that, in some cases, is recharged via wetlands. • In the Kilombero floodplain wetland in Tanzania, 80% of "poor" households and 35% of "better-off" households rely on the wetland for drinking water (McCartney and van Koppen 2004).
Agriculture	• Rice, the staple food for approximately half the world's population (3 billion), is grown largely in natural and human-made wetlands. The total area of global rice production is 153 Mha (i.e., 10% of the world's arable land). • Nonirrigated rice grown on the floodplains of the Inner Niger Delta fluctuates between 40,000 and 200,000 ty^{-1} with yields in the order of 380-1,500 $kgha^{-1}$ (Zwarts et al. 2005). • Flood recession agriculture in the wetlands of the Zambezi is estimated to be worth \$36 My^{-1} (Seyam et al. 2001). • On the Barotse floodplain, Zambia, 28,000 ha of cultivation (including maize, rice, sweet potato, sugarcane, fruit and vegetables) supports approximately 27,500 households and is estimated to be worth \$2.34 million. In the same area, 265,000 head of cattle that graze on the floodplain are valued at approximately \$3 million (Emerton 2005). • 250,000 head of cattle graze in the Kafue Flats wetland (Zambia) during the dry season each year. The market value of these cattle is estimated to be \$4 My^{-1} (Seyam et al. 2001). • In the Kilombero wetland, Tanzania, 98% of households obtain food from wetland cultivation. • There are 258,000 ha of rice fields in the Tonle Sap wetlands. Production in these wetlands is strongly related to the flood regime of the Mekong River (Seng 2007). These fields also provide local communities with other food products, including fish, shrimps, frogs, crabs and snails.

(Continued)

TABLE 2. Examples of different ecosystem services provided by wetlands. (Continued)

Types of ecosystem service	Examples to illustrate importance
Fisheries	• The total catch from inland water (i.e., lakes, rivers and wetlands) was 8.7 megatonnes (Mt) in 2002 (FAO 2004). This compares to 85 Mt from marine capture fisheries and 48.4 Mt from aquaculture. However, in Africa, where many people cannot afford to practice aquaculture, the contribution of inland wild fisheries (2 Mt) to the livelihoods of people is much greater than that of cultured fisheries (283,409 t). • In China, 9.6 million people are engaged in inland capture fishing and aquaculture (Kura et al. 2004). • The livelihoods of approximately 300,000 people are dependent on the fisheries of the Inner Niger Delta (a floodplain wetland). Depending on the flood extent they catch between 40,000 and 80,000 ty^{-1} (Zwarts et al. 2005). • Fisheries resources from the Tonle Sap Lake are estimated to average about 41,740 ty^{-1}, representing 60% of Cambodia's total inland fisheries (Matsui et al. 2006). In some places, fish consumption represents 60-80% of peoples' protein intake (MEA 2005).
Fiber and fuel	• The total area of wetlands in Tanzania (1,828,000 ha) is estimated to generate a gross income from wild resources of \$120 My^{-1} (SARDC et al. 1994). • Reeds and papyrus collected from the Barotse floodplain wetland in Zambia are estimated to have a value to local communities of \$373,000 y^{-1} (Emerton 2005). • In Matang Forest Reserve, Malaysia, 40,000 ha of mangroves annually yield timber worth \$9 million.
Medicine	• The value of medicinal plants collected in the Ream National Park, Cambodia (estuarine wetland including mangroves) is estimated to be \$10,788 y^{-1} (Emerton 2005). • Local people collect eight plant species from the Bumbwisidi freshwater wetland in Tanzania to treat ailments ranging from fever and stomach disorders to chest pains and coughs (McCartney and van Koppen 2004).
Cultural	
Spiritual	• The Lozi people of the Barotse floodplain in western Zambia celebrate the flooding of the Zambezi with the Kuomboka ceremony. • In Lake Fundudzi in the Limpopo Province, South Africa, the Tshiavha community believes that the lake was the home of their ancestral spirits and that survival of the lake ensures the spiritual well-being of that community. They also believe that their ancestors' spirits are responsible for rain, good harvests, peace and property they receive during their lifetime.
Recreational	• Approximately 120,000 tourists visit the Okavango Delta in Botswana each year, generating an income of \$13 My^{-1}. This makes it one of the primary tourist attractions in southern Africa. • Line fishing permits (450,000) are sold annually in South Africa with a total value of \$2.7 million. Although many of these are for marine fishing, an unknown number are for inland fishing. In spite of lack of data, recreational exploitation of freshwater fish on inland rivers and wetlands is known to be extensive (FAO 2008).
Supporting	
Biodiversity	• Globally, wetlands are highly productive and, because of heterogeneity in hydrology and soil conditions resulting in a wide variety of ecological niches, they support immense biodiversity (Junk et al. 2006). • Kafue and Luena Flats, wetlands in Zambia, support an outstanding diversity of organisms including over 4,500 species of plants, more than 400 species of birds and 120 species of fish (Howard 1993).

TABLE 3. Hydrological regulating functions of wetlands.

Water storage
Surface water holding
Groundwater recharge
Groundwater discharge
Flow regulation
Flood mitigation
Water-quality control
Water purification
Retention of nutrients
Retention of sediments
Retention of pollutants

dependence on water and their importance in the hydrological cycle it is essential that wetlands are considered as a key component in strategies for Integrated Water Resources Management (IWRM).

Value of Wetland Services

Many ecosystem services are forms of "public good," accruing outside monetary systems. Consequently, they very often go unrecognized and are often undervalued. Attempts to value some wetland ecosystem services have been made at both the micro and macro scales (Barbier et al. 1997; Mitsch and Gosselink 2000; Terer et al. 2004; Schuyt 2005; Emerton 2005; Adekola et al. 2008). These have demonstrated that the replacement costs for wetland ecosystems are generally far greater than the opportunity costs of maintaining them intact. A crude estimate of the global economic value of wetlands (i.e., the value attributed solely to the physical benefits) is $70 billion a year, of which 7.5% ($5.25 billion) is generated in Africa and 53% ($37.1 billion) in Asia (Schuyt and Brander 2004).

The total use value of Zambia's wetlands (with fish production and floodplain recession agriculture accounting for the main share) was estimated to be the equivalent of approximately 5% of Zambia's Gross Domestic Product (GDP) in 1990 (Seyam et al. 2001). The economic value of wetlands in the Zambezi River Basin is also considerable, with estimates suggesting the economic value in terms of crops alone is close to \$50 My^{-1} (UNEP 2006). In addition, the value of wetland fisheries in the basin is estimated to be \$80 My^{-1}, while the floodplain grasslands support livestock production valued at over \$70 My^{-1}. In Lao PDR, the direct benefits from the 20 km^2 Luang Marsh, which contributes to the livelihoods of some 7,000 households, accrue from fisheries (\$1.28 My^{-1}) as well as rice cultivation (\$350,000 y^{-1}) and vegetable gardens (\$55,000 y^{-1}) (Emerton 2005).

Beyond their purely financial value, the social values of wetlands are also considerable. In many places there is a great deal of local knowledge about wetland resources and the environment as a whole, which often informs traditional practices and customs. Traditional resource management strategies are often in harmony with hydrological regimes and, in many cases, fishing cycles and peoples' socio-political arrangements and settlement patterns have been established to safeguard resources and ensure sustainable use of wetlands (Terer et al. 2004). However, such traditional systems are increasingly under pressure as population rises, people's need for cash income increases, and contemporary management institutions (e.g., formal government) replace customary ones.

Box 4. Flood attenuation function of wetlands (*Source*: MEA 2005).

Gosselink et al. (1981) determined that the forested riparian wetlands adjacent to the Mississippi in the United States during pre-settlement times had the capacity to store about 60 days of river discharge. With the subsequent removal of wetlands through canalization, leveeing, and drainage, the remaining wetlands have a storage capacity of less than 12 days' discharge—an 80% reduction of flood storage capacity. The extensive loss of these wetlands was an important factor contributing to the severity and damage of the 1993 flood in the Mississippi Basin (Daily et al. 1997). Similarly, the floodplain of the Bassee River in France performs a natural service by providing an overflow area when the Seine River floods upstream of Paris. A valuation analysis that highlights the economic need to conserve this natural environment has been presented by Laurans (2001).

Box 5. *Dambo* cultivation: Scientific facts contradict conventional wisdom (*Source*: McCartney 1998).

Dambos, seasonally saturated wetlands, are common in the headwaters of many southern African rivers. Prior to European colonization, the use of the water resources of dambos for the cultivation of crops was a long-established indigenous land-use practice. Traditional systems of dambo cultivation were based on ridge and furrow and basin-like structures to control drainage, runoff and soil erosion (Mharapara 1995). In the early 1900s, European farmers were quick to exploit the 'turf-like' soils in dambos because they were easily ploughed, and the high moisture retention allowed cropping in the dry winter months. European agricultural practices, in particular the introduction of drainage ditches down the central axis of wetter dambos to promote soil moisture conditions suitable for crops like winter wheat, resulted in accelerated gullying and desiccation of dambos on commercial farms (McFarlane and Whitlow 1990). Concurrent with the exploitation of dambos by European farmers, there was a widespread, though scientifically unsubstantiated, perception that, because of their position in the headwaters of rivers, dambos are important in the maintenance of dry-season river flows. Roberts (1938) noted that dambos '*are definitely the source of public streams,'* and Kanthack (1945) wrote that dambos '… *form great sponge areas and hold great quantities of water and are the sources of perennial flow in the main streams and rivers of the drainage systems*.'

The perception developed that the use of dambos for any cultivation was detrimental because of the possible increase in gullying and soil erosion, and the negative influence on downstream river flows. Despite there being little evidence to support it, traditional small-scale farming in dambos was condemned as well as the European farming methods. Legislation introduced in what is now Zimbabwe in the 1920s and 1950s to stop dambos being used for any cultivation resulted in increased deforestation of the upland areas surrounding dambos in order to provide fields for cultivation and increased cattle grazing on the dambos. It is now believed that these practices, rather than protecting the dambos, have in some circumstances, worsened their erosion (Whitlow 1992). Furthermore, there is growing scientific evidence that, contrary to popular belief, most water stored in dambos is lost through evaporation and they play only a very small role in the maintenance of downstream river flows (Bullock 1992). Current research is demonstrating how ridge and furrow methods, partially mimicking traditional practices, enable the water within dambos to be put to productive use in growing crops (particularly shallow-rooted crops) with little impact on dry-season river flows (Mharapara 1995).

Agriculture in Wetlands

Contribution to Livelihoods

The needs of agriculture for flat, fertile land with a ready supply of water mean that wetlands are often a potentially valuable agricultural resource. In arid and semiarid regions with seasonal rainfall patterns the capacity of wetlands to retain moisture for long periods, sometimes throughout the year and even during droughts, means that they are of particular importance for small-scale agriculture, both cultivation and grazing (Box 6).

Although the importance of wetland agriculture is widely recognized, globally there is very little quantitative data on its extent. The global network of "Ramsar" sites (i.e., those wetlands designated as being of International Importance under the Ramsar Convention) currently contains over 1,800 sites covering more than 170 Mha. In both Africa and Asia, at least 90% of these sites directly support human welfare in one way or another. In Africa, 66% of them are listed as used for agriculture (including livestock), whilst the corresponding proportion in Asia is 48% (Table 4). Since the majority of Ramsar sites are conservation areas such values almost certainly underrepresent the percentage of all wetlands in these regions used for agriculture. Interestingly, in Africa a greater percentage of Ramsar sites are used for agriculture than for fisheries, whilst the reverse is true in Asia, perhaps reflecting differences in diet as well as the nature of predominant wetland types on each continent.

Very few studies have determined the value of wetland agriculture; most have focused on the "natural services" provided by wetlands. This is true of the most comprehensive wetland valuation study yet conducted, which undertook a statistical meta-analysis of 385 estimates collected from 181 wetlands from 167 studies worldwide (Ghermandi et al. 2008). This study found that flood control, storm buffering, amenity and aesthetics, and biodiversity are the most highly valued wetland services. Interestingly, although unable to answer questions about sustainability, the study also found that wetland values increase with human pressures and uses, possibly as the "result of an improved level of provision of specific services and the intensity of use of wetlands" (Ghermandi et al. 2008).

A review, conducted for this report, of a very small number of studies that have explicitly included wetland agricultural activities found that in Africa, where it is practiced, wetland agriculture typically contributes to between 6 and 67% of total wetland value, with a mean of 32%. By contrast in Asia, where it is practiced, wetland agriculture contributes to between 3 and 25% of total wetland value, with a mean of 10%. Combining these figures with the estimate of proportion of wetlands used for agriculture and the estimated wetland values given above provides an extremely crude, but probably conservative, estimate of the value of wetland agriculture in Africa and Asia (Table 5).

Although representing a relatively small proportion of the total agricultural GDP of each region, it should be remembered that wetland agriculture is often, though not always, undertaken by the poorest and that, in addition, fisheries and wild food sources add significantly to food security, particularly in years of drought.

In recent decades, agricultural use of wetlands has increased significantly in many developing countries, particularly in Africa, where they are perceived by some as the "new frontier" for agriculture (Wood 2009). This increase is driven partly by population growth, partly by the degradation of overexploited upland fields, and partly by market opportunities and the need to earn cash income (Wood and van Halsema 2008). For poor rural households that are short of food, wetlands can provide a life-saving safety net. Some rural households increasingly use wetlands to supply local markets with irrigated vegetables and other products which generate income. For these households, wetlands represent a development opportunity which can lead them out of poverty (Box 7). However, in some places, relatively

Box 6. The water resource opportunities provided by dambos for small-scale farming in Zimbabwe (*Source*: McCartney et al. 1997).

In Zimbabwe, with its savanna climate, dambos are estimated to occupy about 1.3 Mha. Populations have to cope with both seasonal and interannual shortages of water as a matter of course. Under such circumstances, wetland environments that retain water close to, or at the ground surface, represent a water reserve that can be used to bridge mid-season droughts and extend the length of the growing season. Consequently, the water resources of dambos are widely utilized as an alternative, or a supplement, to rain-fed agriculture. In the communal farming areas of Zimbabwe, many thousands of hectares are cultivated. Most often this takes the form of cultivation of maize, rice and vegetables in small gardens. The intensity of cultivation varies considerably, but in some communal regions an average of 30% (actual values vary from 5 to 75%) of dambo area is cultivated and in some instances this cultivation has been continuous for decades.

The catenal variations in soil and water properties make dambos difficult to utilize for large-scale agriculture but are exactly the features which provide opportunities for small-scale farmers. Wet patches mixed with dry soils mean working of areas containing dambos as a single unit is difficult, and generalized methods of large-scale farming are inappropriate. Attempts by European colonists in the first half of the twentieth century to drain dambos to produce uniform conditions resulted in rapid soil erosion, environmental deterioration and the drying out of dambos. However, at a small scale farmers in communal areas can use each part of the slope in a different way, thereby reducing the risks of crop failure. The use of dambos requires flexibility in approach because the extent of soil-moisture retention varies from year to year depending on the rainfall. In drier years sequential cropping may not be possible, while in wetter years although multiple cropping of greater diversity may be possible, waterlogging may be a problem in certain places. Indigenous farming practices that combine dry upland farming with wetland cultivation have adapted to this variability.

Sowing and harvesting dates for various vegetables grown in trials on a dambo at the Marondera Horticultural Research Centre, Zimbabwe, illustrating extension of the growing season.

Season	Total rainfall (mm)	Rain		Length of growing season (days) •	Crop	Date		Extension of growing season (months)• • •
		Start	End			Sowing	Harvest	
1988/89	876	Oct.	Mar.	140	Leafy vegetables• •	12/4/89	23/8/89	5
1989/90	946	Oct.	Apr.	180	Leafy vegetables	26/9/89	1/12/89	0
					Leafy vegetables	19/3/90	07/05/90	0
					Potato	17/10/89	2/90	0
					Potato	19/6/90	29/10/90	8
					Tomato	9/3/90	28/8/90	4
1990/91	453	Nov.	Feb.	100	Cabbage	12/2/91	3/6/91	3.5
					Green beans	7/2/91	9/4/91	ca. 2

• Estimated from data on rainfall and potential evapotranspiration.

• • Leafy vegetables comprise rape, *tsunga*, kale and cabbage.

• • • Due to residual and lateral movement of soil moisture.

TABLE 4. Wetland use in Ramsar sites of international importance in Africa and Asia (Mha in parentheses).

Wetland use	Percentage of sites	
	Africa	Asia
Agriculture (including livestock)	66 (61)	48 (6)
Fisheries/aquaculture	56 (57)	60 (8)
Wetland products	42 (48)	35 (7)
Domestic water supply	17 (15)	11 (2)
Recreation/tourism/conservation	65 (49)	71 (9)
Any of the above uses	90 (65)	97 (13)

TABLE 5. Estimate of the financial value of wetland agriculture.

	Wetland area (Mha)	Estimated total value of all wetland services (billion $)	Estimated value of wetland agriculture (billion $)	Total agricultural GDP (%)
Africa	131	5.25	1.1	1.5
Asia	286	37.10	1.8	3.9

Box 7. Wetland agriculture as a route out of poverty (*Source*: Sampa 2008).

Cecilia Pensulo lives in the Mpika District of Northern Zambia. When her husband left her she had to bring up four children by herself. She started working as a farm laborer for other farmers, but found that she could hardly support herself and the children from such irregular income. She felt that she had to farm herself and was aware that there was plenty of land available in the dambo (i.e., seasonal wetland) near her village. With help from a local NGO she learned that with new methods this previously unusable land could become productive. In her first year of cultivation in the dambo she managed to develop only a very small area, but the crops were good and the prices high. As a result, she met her household costs and could also send her children to school again. In her second year, she managed to prepare 0.25 ha and from the pumpkins, squash and tomatoes she sold to traders from the nearby district headquarters she managed to make over $200, a small fortune by local standards.

Cecilia Pensulo grading her farm produce. She is paying the two farm assistants for helping harvest the produce. Previously she was a farm laborer herself (*Photo credit:* Jonas Sampa).

Since then she has not looked back. She invested some of her dambo profits in chicken-rearing, and is now on her seventh set of broilers, which every 3 to 4 months yield her a profit of approximately $300. Her wetland farming is still ongoing, but less intensive now that she has diversified into this other enterprise. However, she says that she will never give up dambo cultivation as it provides her family with food during the hungry period as well as income to meet household needs. As a successful and respected member of her community, Cecilia has been elected the Secretary for the Community School, something she can manage to do now that her household is food-secure. Hence, dambo cultivation has also helped her have a voice in her community and be socially empowered, thereby enhancing her overall well-being.

wealthy households are appropriating wetlands for commercial production and using wetland agriculture as a means of accumulating financial capital (Woodhouse et al. 2000).

Farmers are often very skilled in the management of water within wetlands. Throughout Asia complex systems have been devised to control not only the frequency and timing of flooding but also the depth and duration of standing water in paddies. Such systems often incorporate drains, canals, bunds, terraces and ridges. Similar systems are also used in the *inland valley* wetlands of West Africa. Very often such interventions require little capital investment and have been tailored to the particular hydrology and morphological characteristics of an individual wetland (Box 8). Through greater control of water, farmers are able to extend the growing season and reduce risks arising from the consequences of either drought or flooding. However, very often there is little consideration of the wider environmental impacts, and hence the consequences for other ecosystem services.

The Food and Agriculture Organization of the United Nations has highlighted the importance of wetlands for agriculture in Africa (Frenken and Mharapara 2002) and many African governments and NGOs are encouraging wetland farming to improve food security, reduce poverty and facilitate the diversification of rural livelihoods. In common with all forms of agriculture, the contribution that wetland agriculture makes to household income is dependent on a wide range of biophysical and socioeconomic factors including climatic conditions, the wealth status of households and access to markets (Box 9). Globally, wetland food provisioning, which comprises fisheries and wild foods as well as agriculture, is estimated to range from \$6 to \$2,761 $ha^{-1}y^{-1}$ (de Groot et al. 2002).

Wetland Degradation as a Consequence of Agriculture

Although wetland agriculture can bring significant benefits in terms of food security, health and income, ill-considered development often results in wetland degradation, deleterious environmental impacts and harmful consequences to peoples' livelihoods. Impacts on wetlands can be derived from human activities that occur within wetlands and, because of the interconnectedness of the hydrological cycle, also from activities that take place within the wider catchment. Through removal of water or by alteration of natural flow, chemical, and sediment regimes, human exploitation of both surface water and groundwater resources can have major detrimental consequences for wetland ecosystems.

Policies in the agriculture sector have been some of the key drivers of change in wetlands in many parts of the world (Box 10). Clearing and draining wetlands for agricultural expansion and the modification of hydrological and other fluxes have been the primary cause of wetland degradation in the past. Damming of rivers, withdrawal of river water and groundwater abstraction have all resulted in the desiccation of many wetlands (Box 11). Pollution from the use of fertilizers and pesticides has adversely impacted natural biota (including fish) and undermined the ecological character of many wetlands. It is estimated that more than 50% of some wetland types in North America, Europe, Australia and New Zealand have been lost, largely as a consequence of human activities directly related to agriculture (MEA 2005). In contrast, it has been estimated that by 1985, 27% of wetlands in Asia (i.e., about 80 Mha) and 2% of wetlands in Africa (i.e., about 3 Mha)[3] had been drained for intensive agriculture (MEA 2005).

Today, agriculture remains the greatest threat to natural wetlands. For example, in recent years production of palm oil for biofuels has resulted

[3]Number of hectares based on estimate of total areal extent of wetlands in Africa and Asia (see section, *Wetland Extent and Distribution on page 2*).

Box 8. Examples of agricultural water use in the GaMampa wetland, South Africa (*Source*: adapted from Chuma et al. 2009).

Drainage ditch in a wetland field (*Photo credit:* Matthew McCartney).

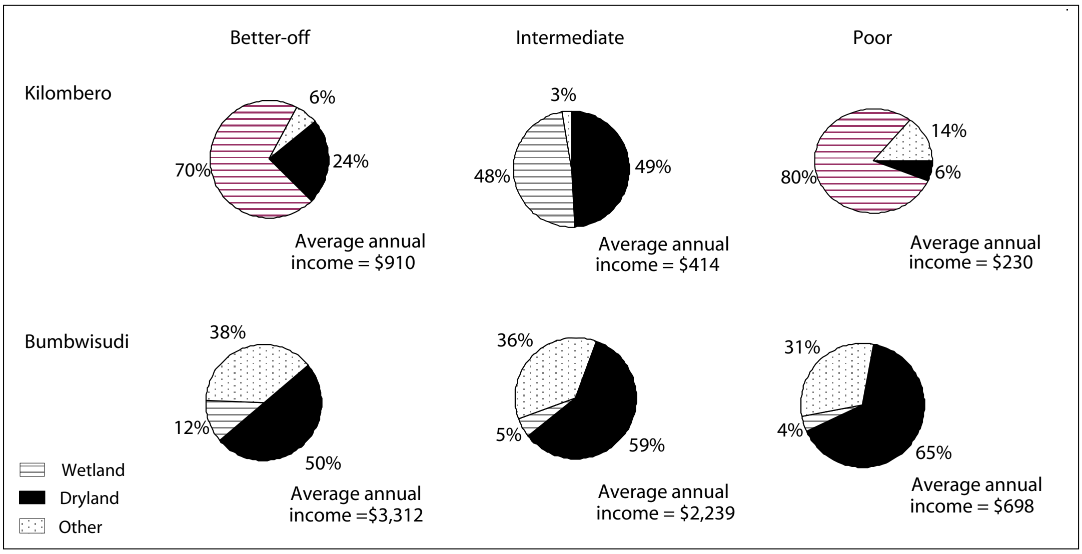
Due to a shallow water table most of the fields in the GaMampa wetland have a high soil moisture content. In many places residual soil moisture is sufficient to grow crops throughout the year. However, in places where moisture conditions are not ideal, farmers intervene to improve the situation. In the parts of the wetland which are too wet for maize and vegetables in the wet season, open drainage channels have been dug to reduce waterlogging. During the dry season, the ends of the same channels may be blocked to reduce drainage and, if necessary, to raise water levels for flood irrigation of fields. In this way farmers are able to tailor soil moisture conditions precisely between, and even within, plots.

Water management intervention	Infrastructure or form of intervention	Location	Season	Comments
Direct use of residual moisture during dry or rainy season	Ridges and furrows in some places	Across the entire wetland	Wet and dry seasons	Main source of crop water; no irrigation infrastructure
Drainage	Open channel drains	Within 100 m of the river	Usually, wet season	To lower the water table to create a suitable environment for crops, farmers need advice on how to avoid desiccation of the wetland
Supplemental irrigation	• Springs and shallow wells in the wetland • Irrigation canals from shallow wells and springs • Flooded basins • Small pumps to access shallow groundwater	In the transition zone between the wetland and the dry uplands	Dry season, but also rainfall season during low rainfall years or during mid-season droughts	Farmers need advice on innovative interventions for more efficient water use

in the draining of approximately 12 Mha of peatlands in Southeast Asia (primarily Malaysia and Indonesia). The loss of ecosystem services, arising because of the degradation of wetlands, can have devastating consequences for the people, often the poorest, who depend on them. Adverse ecological changes can have negative effects on food and fiber production and may negatively affect overall agricultural productivity (Falkenmark et al. 2007). For example, the construction of the Bakolori Dam on the Sokoto River, a tributary of the Niger River, to supply irrigation water for 30,000 ha of crops, resulted in decreased downstream wetland inundation

Box 9. Wetland cultivation in Tanzania: Contribution to household cash income (*Source*: McCartney and van Koppen 2004).

Comparison of cash income generated by cultivation in two wetlands in Tanzania illustrated considerable differences in terms of both absolute income and the proportion generated through wetland activities for poor, intermediate and better-off households.



The values presented are those reported by the householders themselves. No attempt was made to determine net income by subtracting labor or other input costs. Furthermore, no attempt was made to quantify in cash terms the consumption by households of their own produce (i.e., crops and livestock produce) or the consumption of "free" environmental resources including wild foods, firewood, livestock grazing and construction materials.

In the Kilombero Valley the contribution of wetland cultivation to cash income was 66% of the approximately \$518 household^{-1}y^{-1} but this average masks differences between wealth classes. For poor households, 80% of their cash income was generated from wetland cultivation. In contrast, the intermediate and better-off households obtained 70 and 48% of their total cash income, respectively, from wetland cultivation. The households of the Bumbwisudi wetland were wealthier than those in the Kilombero Valley. In this case, the contribution of the wetland to cash income was relatively small. For poor households, only 4% of their cash income was generated from the wetland. In contrast, the intermediate and better-off households obtained 5 and 12% of their cash income, respectively, from the wetland. The relatively low contribution of the wetland to cash income, across all the wealth classes, resulted from the fact that the wetland was used primarily for growing rice, the staple food. Generally, the poor households consumed nearly all of the rice grown. Only the better-off households had wetland plots large enough to grow surpluses for sale.

The differences between the case studies are explained by variation in biophysical conditions and socioeconomic opportunities and constraints. For Bumbwisudi, the relatively high rainfall provides opportunities for dryland cultivation and greater diversification of crops. Furthermore, the easily accessible markets ensure that produce can be sold relatively easily. In contrast, in the Kilombero Valley farming opportunities are hampered primarily by lower rainfall, poor communications and a lack of market opportunities.

These results are similar to the findings of other studies focused on African wetlands, which have found a wide range in household income generated from wetland crops. In the GaMampa wetland in South Africa the average annual value of cultivation per household was estimated at \$93 (Adekola et al. 2008); the corresponding value in Nakivubo urban wetland, Uganda, was \$300 (Emerton 2005); in Barotse wetland, Zambia, \$109 (Turpie et al. 1999); in the Lower Shire, Malawi, \$363 (Turpie et al. 1999); and in the Chipala Ibenga wetland, Zambia, \$19 to \$107 (Masiyandima et al. 2004)

Box 10. The conversion of the Sanjiang Plain from wetland to farmland: The role of policies (*Source*: Senaratna Sellamuttu and de Silva 2009).

In 1949, the Sanjiang Plain in Heilongjiang Province, China, comprised a vast wetland system of rivers, seasonally flooded marsh and grassland stretching over 5.36 Mha. Today, the wetland is reduced to just 0.8 Mha. China's economic progress and the conversion of the Sanjiang wetlands are linked because it was government policies, intended to drive economic growth and alleviate poverty, which caused the major change in the wetlands.

Following the Second World War and the Communist Revolution, food security emerged as a primary constituent of national development, and the conversion of land for agriculture remained a dominant feature of national policies throughout the second half of the twentieth century. Policies of population expansion and internal migration encouraged the opening of new farmlands by discharged soldiers in the 1950s. Further conversion occurred in the 1960s when, as part of the Cultural Revolution, urban youth were sent to work in agrarian communities. As a result of these policies, more than 7 million people moved into the Heilongjiang Province and farmlands that covered 811,000 ha of Sanjiang in 1949 reached 3.5 Mha in 2000. Conversely, over the same period, wetland area declined from 5.36 to 1.04 Mha. When national grain production reached 512,295 tons in 1998, it appeared that China's food security requirements had been met. Furthermore, the number of people living in absolute poverty had dropped from 250 million in 1978 to 32 million in 2000. Because of these achievements, perhaps influenced by the emergence of an international discourse on sustainable development and China's membership in the Ramsar Convention in 1992, further conversion of wetlands of the Sanjiang Plain was halted in 1999. In 2004, the General Office of the State Council issued the *Notice on Strengthening the Management of Wetland Conservation*, and several Nature Reserves were established in the Sanjiang Plain, including a Ramsar Site. However, in the same year the government also introduced a series of economic incentives to consolidate agricultural gains. These included guaranteeing minimum prices for grain and a grain subsidy as well as a suite of subsidies targeting agricultural inputs. Therefore, agriculture remains attractive. Even though a recent study estimated that losses in ecosystem services, arising from conversion of wetlands to farmland on the Sanjiang Plain, equate to \$15.6 billion y^{-1} (Wang et al. 2006), it remains to be seen if the policies intended to conserve the remaining wetlands will be effective.

Unconverted wetland (*Photo credit:* Sanjiv de Silva).

Farmland (*Photo credit:* Sanjiv de Silva).

and the loss of 12,000 ha (out of 17,000 ha) of flood recession agriculture on which some 50,000 people depended. The predicted irrigation benefits of the dam did not materialize and, in addition, fish populations declined, with lower catches and smaller sizes forcing more and more households to abandon fishing. As a result, many people were forced to migrate from the area (Adams 1985).

In many instances, wetland degradation and high levels of poverty go hand-in-hand. In a recent review of seven wetland case studies, this was a

Box 11. Impact of upstream irrigation on the Usangu wetland, Tanzania (*Source*: McCartney et al. 2008).

The Usangu wetlands constitute one of the most valuable inland wetlands in Tanzania, supporting large numbers of people through provision of livestock grazing, fisheries and other livelihood activities such as brick-making. Over the past 30 years, there has been a rapid expansion of cultivation in the catchment. Analysis of Landsat images shows an increase in cultivated areas from 121 to 847 km^2 between 1973 and 2000. There has also been an increase in irrigation, particularly of rice. Between 1970 and 2002, the irrigated area increased from approximately 10,000 to about 44,000 ha. Much of this irrigation, which comprises large state-owned rice farms as well as formal and informal smallholder plots, is located on fertile alluvial deposits immediately upslope of the wetlands. Water is diverted from both perennial and ephemeral rivers draining into the wetlands.

The Usangu wetlands are drained by the Great Ruaha River. Historically, the river was perennial with the flow continuing throughout the dry season in all but exceptionally dry years. However, since 1993, as a consequence of upstream diversions, water levels in the Ihefu swamp have dropped below the crest of a natural rock outcrop and consequently flows have ceased for prolonged periods during the dry season of each year. The drying of the river has had severe social and ecological consequences. It has resulted in social conflicts between upstream and downstream users. In the dry season, women and children have to spend much of their time searching for water, with some walking up to 20 km to locate sources. The cessation of flow is also having adverse impacts on the ecosystem of the Ruaha National Park, located approximately 30 km downstream. The reduced flow in the dry season has directly caused the death of many aquatic animals and disrupted the lives of many others that depend on the river for drinking water. There is concern that the death of so many animals and the reduction in the aesthetic appeal of the river are reducing the number of tourists visiting the Park.

Results from a simple hydrological model developed for the Ihefu swamp (located within the wetland) indicate that between 1958 and 2004, dry-season inflows declined by approximately 60% and the dry-season area of the swamp decreased by approximately 40% (i.e., from 160 to 93 km^2). The model also shows that to maintain minimum downstream environmental flows (estimated to be 0.5 m^3s^{-1} through the Ruaha National Park) requires a minimum inflow of 7 m^3s^{-1}, which is approximately 65% greater than what occurs currently. There is significant potential for improving water use efficiency in the irrigation schemes. However, given the socioeconomic importance of current levels of water withdrawal, such an inflow may be difficult to achieve. Consequently, other options, including upstream storage and improved water management within the wetland itself, should be considered.

Inspection of the dried riverbed of the Great Ruaha River at NG'iriama, Usangu Plains (*Photo credit:* Bruce Lankford).

common feature. However, whether poverty was a driver of wetland degradation or its result varied from case to case (Box 12). What is clear is that once wetland degradation began, a vicious spiral set in with one problem making the other worse in an ever-deepening cycle of environmental degradation and poverty (Senaratna Sellamuttu et al. 2008b).

Box 12. Wetland degradation and poverty linkages (*Source*: Senaratna Sellamuttu et al. 2008b) (Continued).

Poverty as a result of wetland degradation

The Hadejia-Nguru wetlands constitute an inland delta in northern Nigeria, located where the Hadejia and Jamaare rivers combine within the Komodugu-Yobe Basin. The basin supports a population of 18 million, 1.5 million of whom reside within the wetland. The predominance of farming, fishing, livestock-rearing and collection of wild resources indicate a high dependence on the rich wetland ecosystems. Since 1971, a series of dams have been constructed on the main tributaries to provide water for cereal irrigation. Although the yields from intensive irrigation schemes are higher per hectare than from floodplain agriculture, the total value of wetland benefits exceeds that from the irrigation: \$167 ha^{-1} from the wetland compared to \$29 ha^{-1} from irrigated agriculture. Since the construction of the dams and irrigation schemes, drastic changes have occurred in the wetland. The flood extent has dwindled from 2,000 km^2 to 413 km^2. Poor dam design and operation have altered both the volume and timings of water flow in the basin, subjecting some parts to prolonged flooding and others to prolonged drought. The resulting wetland degradation undermined many key livelihoods and restricted access to infrastructure and services such as credit and markets. Livelihood failures severely aggravated poverty and resulted in abandoned villages and further ecological degradation as people exploited other natural resources to cope with the loss of primary production systems.

Lake Fundudzi which covers 144 ha is South Africa's only inland freshwater lake. Dependence on the wetland is high as the area's primary productive resource. The lake's fisheries are the main source of protein for the majority of households and its water is used to support livestock. In an attempt to improve food security, a large number of new commercial and smallholder fruit orchards and vegetable gardens were established in the catchment and cultivated both in winter and summer. Poor land use planning resulting from a fragmented institutional scenario and poor awareness meant the clearing of natural vegetation for cultivation, and housing was haphazard and began to drive excessive lake sedimentation. This was exacerbated by cultivation on steep slopes without measures for soil-erosion control. Promoting participatory wetland rehabilitation and land use planning for sustainable land use to bolster local incomes thus became the priority for the Mondi Wetlands Project.

Wetland Values and Trade-offs: Maintaining a Range of Services

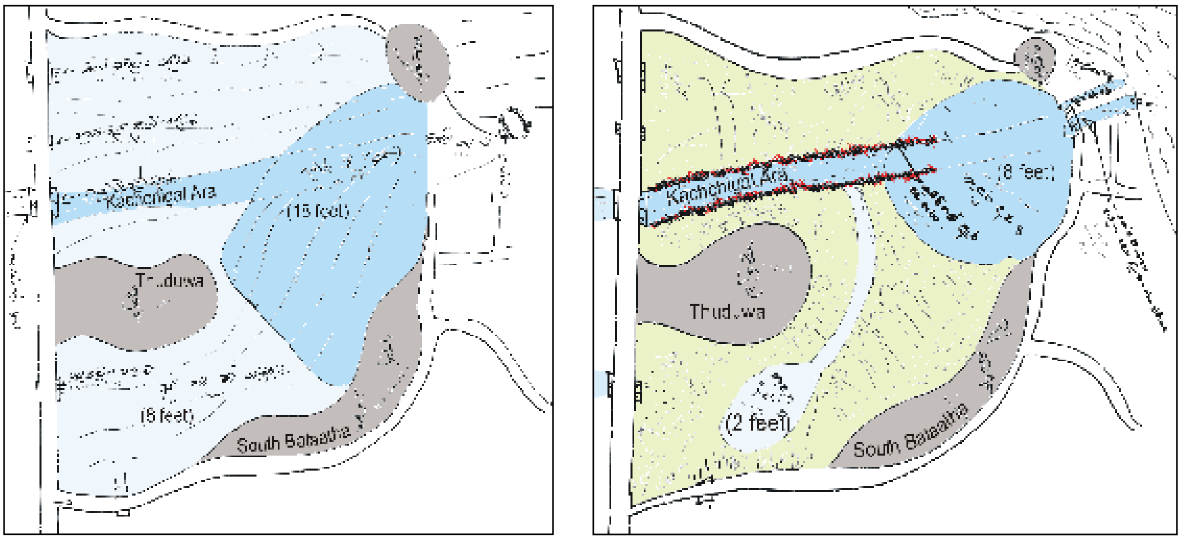
Although in the short term the agricultural development of wetlands results in an increase in the provision of food, in the long term it often increases the input of pollutants, removes their natural filtering function, and reduces other ecosystem services. Any agricultural activity within a wetland will alter its ecological character to some extent. Although smallholders growing for subsistence agriculture may only cause relatively small changes in other services, in common with almost all development activities, there are usually trade-offs associated with wetland agriculture.

Agriculture in and around wetlands can lead to conflict between farmers and other wetland users (Box 13). The most frequent impact of the development of wetland agriculture is losses in subsistence agriculture, which are offset by gains in market-orientated agriculture, where the latter is often associated with a monoculture and intensive water use. Hence, agricultural intensification in wetlands often results in groups of people reliant on subsistence agriculture losing out, with a negative feedback cycle occurring where productivity losses lead to further expansion and transformation of wetland areas (Wood and van Halsema 2008).

Box 13. Conflicting interests and trade-offs associated with agriculture and wetlands (*Source*: Senaratna Sellamuttu and Clemett 2003).

In the area of the Kalametiya coastal wetland lagoon on the south coast of Sri Lanka there is considerable competition for water between rice paddy farmers and lagoon fishermen. The fishermen have been severely impacted by changes to the condition of the Kalametiya Lagoon which began to decline almost 40 years ago, mainly due to upstream irrigation development and the construction of a permanent outlet to the sea. Bunds built along Kachchigal Ara, the main inlet to the lagoon, to prevent flooding of the paddy fields have compounded the problem. Consequently, the proportion of households undertaking lagoon fishing has declined by 20 and 60% in two of the villages adjacent to the lagoon. Those who continue to fish find it virtually impossible to make a living. These families want to see the bund along Kachchigal Ara removed and the outlet to the sea blocked so that the lagoon can be restored to its former size. They hope that with these changes the lagoon fishery will be revived. However, if these restorative actions are taken, hundreds of paddy farmers will be adversely impacted and therefore the opinion of the farmers is very different. Their solution would be to increase the bunds along the Kachchigal Ara and to construct a series of drainage canals directly to the sea to prevent flooding of their land. It appears that greater understanding must be developed between the farmer and fisher groups and compromises made, which may be possible through a forum that includes representatives from different resource user groups. However, these problems may have been avoidable if those state agencies responsible for planning regional development at the catchment level had taken an approach that included livelihoods and poverty analysis, and used a scenarios-based approach to determine the most appropriate intervention for all wealth groups and resource users including those engaged in farming and fishing.

(a) (b)



Resource maps as drawn by fisherman (a) wetland in the 1970s, and (b) wetland in 2001.

Clearly, there is a need to manage wetlands for multiple ecosystem services and have that aligned with livelihood strategies. Although in many cases this means a greater emphasis on conservation to protect key functions, managing wetlands for livelihoods is not necessarily congruent with managing them solely to protect biodiversity. There will often be conflicts and trade-offs between livelihood requirements and conservation needs that require skillful and innovative forms of management to overcome (Box 14). The objective of addressing these trade-offs should not be to maximize values for conservation and poverty reduction

Box 14. Managing wetlands for livelihoods and wildlife (*Source*: Senaratna Sellamuttu et al. 2008b).

In the Cao Hai wetland reserve in China, there was serious conflict between the Nature Reserve (NR) authority and local communities. The authority rigidly enforced rules that prohibited people from using the wetland, and local people in turn saw little option but to challenge the rules. The authority wanted to maintain the ecosystem's integrity, while the people were concerned about food security and other basic needs. An International Crane Federation project in Cao Hai recognized the importance of both needs, and made clear the role of dialogue and compromise if the issue was to be resolved. Equal weight was thus given to understanding the challenge from the 'wetland for biodiversity' perspective and the 'wetland for people' perspective, with the aim of identifying where a mutually acceptable compromise lay. To implement this strategy, the project took particular care to involve a broad range of skills that covered both ecological and social sciences. The ecological skills helped understand the nature and productivity of the wetland while the social skills helped create avenues for dialogue between the NR staff and the communities. This took the form of an effective micro-credit scheme that sought to raise household incomes whilst reducing their dependency on the wetland. By involving the NR staff in administrating this scheme, dialogue and an understanding of each other's perspectives were possible. One result was the willingness of both groups to compromise which cleared the way for a zoning plan whereby the wetland would support the needs of both biodiversity and local communities.

simultaneously but rather to produce net benefits for people whilst at the same time avoiding fundamental ecological threats and ensuring the long-term sustainability of different ecosystem services (Senaratna Sellamuttu et al. 2008b). Hence, a pluralistic approach is required that provides an opportunity to increase the overall productivity of a wetland whilst ensuring livelihoods and food security are enhanced rather than harmed by agricultural development. To this end, it is essential that competing uses of wetlands, and the water that flows into them, are explicitly considered in wetland management (Nguyen-Khoa et al. 2008).

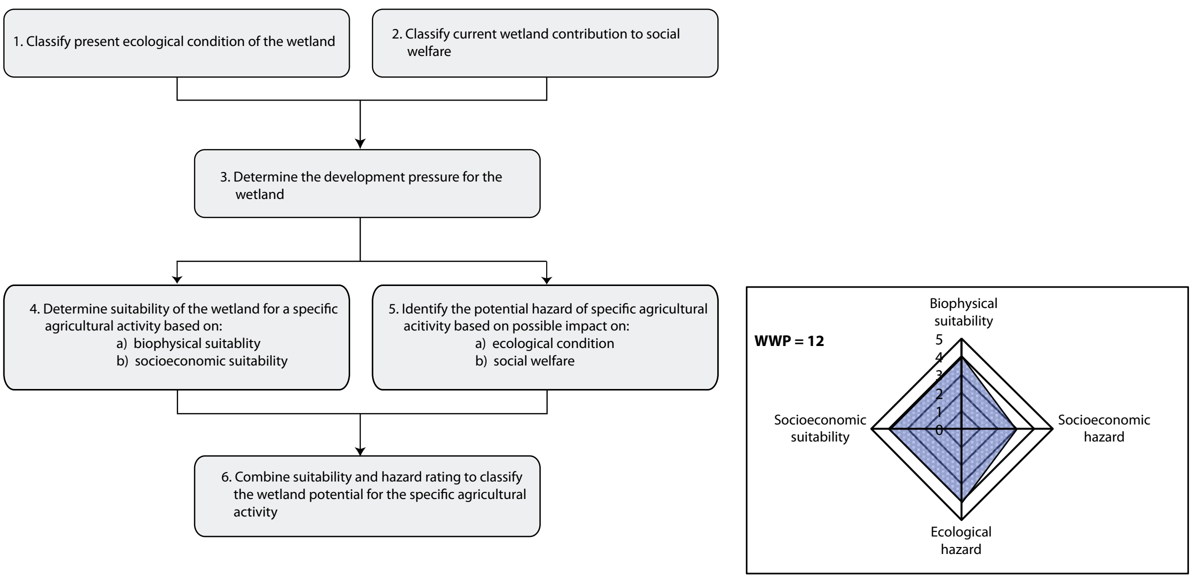
The Comprehensive Assessment of Water Management in Agriculture (CA) emphasized that drivers of wetland conversion for agriculture will intensify over the next three decades as the demand for increased economic output and food production rises rapidly. The drivers for change will be most severe in developing countries with rapidly expanding populations. In recognition of this, the CA has stressed the need to identify i) how the ecosystem services that contribute to agriculture can be enhanced, and ii) how agricultural activities can be designed to contribute to ecosystem functioning (CA 2007). In future, much greater emphasis is needed on the sustainable use of wetlands and in managing them for multiple, rather than single, services. This is likely to be particularly important under future climate change scenarios when wetlands may be vital components of a community's adaptation strategies, and simultaneously the demand for regulating services provided by wetlands is likely to increase. Methods that make explicit trade-offs between different services are a prerequisite to improved wetland management and sustainable development (Box 15).

Traditional methods of trade-off assessment are based on variations of cost-benefit analyses that are dependent on the financial evaluation of different aspects of a system. However, it can be extremely difficult to define the value of many ecosystem services in monetary terms. Researchers continue to develop techniques to make explicit, and quantify, the trade-offs, associated with different wetland uses (Jogo et al. 2009). Nonetheless, a lot remains to be done to improve these techniques. Even where trade-offs are understood, more emphasis is needed to better integrate this information into broader policy processes dealing with both land use planning and water allocation as well as issues of social equity. Failure to do this will perpetuate the disconnection between on-the-ground research and policymaking.

Box 15. Working wetland potential (WWP): An approach to evaluating trade-offs in relation to wetland agriculture (*Source*: McCartney et al. 2005).

The Working Wetland Potential (WWP) provides a framework for identifying, organizing and analyzing the complex factors that link people, agriculture and wetland ecosystems. The concept seeks to add value to the benefits (i.e., ecosystem services) provided by a wetland, without undermining either the biophysical or socioeconomic sustainability of the system; that is, support the *wise-use* of the wetland, for agricultural purposes, while maintaining the essential elements of its ecological character. The potential of proposed wetland development activities is considered in relation to long-term wise-use of the wetland. The method is a pragmatic approach for explicit consideration of agriculture in the evaluation and prioritization of options for the sustainable development of wetlands.

The method is based on a form of multi-criteria analysis that integrates biophysical and socioeconomic aspects of wetland utilization. The WWP index emerges from the aggregation of two values, the first arising from an appraisal of both the biophysical and socioeconomic suitability of using the wetland for agriculture; and the second resulting from an assessment of the possible hazards, in relation to both social welfare and the ecological character of the wetland. Hence, the approach provides a way to explicitly integrate biophysical and social aspects of wetland utilization in a single index to enable an initial assessment of the suitability of using a wetland for agriculture. More details and example applications of the approach are provided in McCartney et al. 2005.



Schematics of the approach to determining the Working Wetland Potential and example of the graphical representation of the index.

Discussion

It is social and economic factors that drive human-induced changes to the condition of wetlands. In any given situation, the underlying causes are a complex mix of policies, practices for economic growth, demographic changes and inequities in the control of resources. Often, it is attempts to maximize benefits through exploitation of certain functions that result in changes to the condition of a wetland. In the past, many wetlands have been extensively modified to increase their agricultural productivity. Agricultural interventions, both within wetlands and in their catchments have, often, significant effects on the ecology and hence on the functioning of wetland ecosystems. While the ability of a wetland to provide food may be increased, other potential benefits may be reduced or lost. Too often in the past, wetland utilization has exploited one dominant service, with little or no consideration of the range of benefits provided or of the trade-offs being made.

As described in this report, the research undertaken by IWMI and others has shown the following:

- Wetland ecosystem services provide a wide variety of tangible and intangible benefits to large numbers of people in Africa and Asia. The way they do so is complex and multifunctional and is directly related to the type of wetland and its condition at a particular given time.
- Wetland agriculture, which can be viewed as a provisioning ecosystem service, provides a development opportunity and a poverty reduction strategy for many poor people, but care is needed to ensure that other ecosystem services including other means of food security (e.g., fisheries), also vital for poor people, are not lost.
- Astute management that incorporates appropriate water and agricultural practices, within wetlands and their surrounding catchments, can result in a net increase in the benefits derived from wetlands.
- Wetlands can be considered natural hydraulic infrastructure, bestowing many water resource benefits, and these need to be carefully considered in planning and management of wetlands.

Currently, very few governments have specific wetland policies and few national strategies/policies pertaining to either water or agriculture that make explicit reference to wetland agriculture.[4] Wetlands are consequently influenced by the policies of many different sectors. If future wetland agriculture is to bring about net benefits a much more strategic approach to wetland utilization is required.

Developing appropriate policies for wetlands is not easy. Often, wetlands are covered under multiple sectors with no single sector being in overall charge. Moreover, the complex nature of livelihoods and their relationships to linked systems of natural resources make it difficult to identify and define authority structures that can take overall responsibility for wetland resource use and management. Furthermore, enforcement of formal regulations for wetland use and agriculture will be unlikely to succeed in countries that lack the resources to monitor and police wetland utilization. Pragmatically, it seems that a policy framework for sustainable wetlands management requires two key features. The first is that maintaining the ecological integrity of wetlands should be clearly incorporated in policies dealing with larger landscapes (e.g., river basins, provinces, etc.). The second is a mechanism that empowers local people to manage and control wetlands in their own landscape. The challenge in this case is to devise self-regulating and self-enforcing incentives for sustainable management and to contribute to the development of policies that facilitate their implementation. In many cases, one aspect

[4]In Africa, exceptions include Uganda, which has a National Policy for the Conservation and Management of Wetland Resources (1995) and Zambia, where the opportunities for small-scale irrigation in seasonal wetlands are highlighted in the National Irrigation Plan (2004).

without the other is unlikely to be sufficient in cases where a wetland is vulnerable to changes in water regime and other land use practices. Such policies however cannot materialize without adequate political will underpinned by an adequately clear rationale based on the multiple and everyday contributions made to people's well-being by wetlands.

Concluding Remarks

Paul Mafabi, Commissioner of the Wetlands Management Department in Uganda's Ministry of Water and Environment recently stated: *Wetlands affect the daily lives of every one of Uganda's citizens and provide a powerful wall of protection for Uganda's economic development*. The same could be said for many countries in Africa and Asia. Data are scarce, but subjective understanding is clear: throughout much of the developing world wetlands are vital to the livelihoods of many millions of people.

Farmers can enhance the natural productivity of wetlands, and wetland agriculture can be viewed as an ecosystem service that can, and does, make an important contribution to livelihoods, food security and poverty reduction. However, if mismanaged, it can result in degradation and loss of other ecosystem services. Consequently, it is widely perceived simply as a threat to wetlands. Wetland policies too often reflect this negative view and ignore the benefits of wetland agriculture for many people. As populations rise and climate change adds to stresses on dryland farming, human pressures on wetlands will inevitably increase. In common with the past, much of this pressure will arise from agricultural activities occurring directly within wetlands as well as the surrounding catchments.

Wetland policies and management regimes need to better reflect the realities of wetland agriculture in developing countries. The dilemma remains how to maximize the benefits of agriculture whilst simultaneously minimizing the adverse impacts on other valuable ecosystem services. Research is required to better understand trade-offs and determine best management practices.

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