General introduction to the report

The origins of the Guidelines on Agriculture and Wetlands Interactions (GAWI) initiative go back at least as far as October 2002. At that time and in two consecutive weeks, in Valencia (Spain), there were the Global Biodiversity Forum 17 (GBF17) workshop "Wetlands and agriculture" and Resolution VIII 34 at the Eighth Meeting of the Conference of the Contracting Parties to the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar COP8) titled "Agriculture, wetlands and water resource management". Together, these put the issue of the relationship between agriculture and wetlands clearly on the international agenda. In particular, the latter requested the Ramsar Scientific and Technical Review Panel (STRP), in the 2003–05 triennium, "to establish a framework for identifying, documenting and disseminating good agriculture-related practice, including site-specific and crop-specific information, and policies that demonstrate sustainable use of wetlands for agriculture" (Annex 1).

Since that date, further initiatives, such as the Joint FAO/Netherlands Conference on Water for Food and Ecosystems in the Hague in January 2005, have emphasized the need for new approaches to take into account water and water-related ecosystems in the search for more sustainable use of water in agriculture. This theme has been followed up most recently in the Comprehensive Assessment of Water Management in Agriculture (CA, 2007), which follows up on a number of themes raised by the Millennium Ecosystem Assessment (MA, 2005a). Other initiatives relevant to this area include the Challenge Program on Water and Food (CPWF) of the Consultative Group on International Agricultural Research (CGIAR), the International Assessment of Agricultural Science and Technology for Development (IAASTD) and the Ramsar – Convention on Biological Diversity (CBD) Joint Workplan.

The GAWI group consists of the Ramsar Secretariat, FAO, Wageningen University and Research Centre (WUR), International Water Management Institute (IWMI), and Wetlands International (WI). In addition, Wetland Action (WA) joined the group in September 2006. The group was set up at Ramsar COP9 in Uganda (November 2005) with support from the Netherlands and Swiss national delegations. These delegations and the GAWI partners wanted to support the Ramsar Secretariat and STRP in addressing the issue of the interaction between agriculture and wetlands. The GAWI group takes its title from the project in which it has agreed to collaborate: "Guidelines on Agriculture, Wetlands and Water Resource Interactions (GAWI)".

The overall goal of the GAWI project is: "To promote synergies between agriculture, wetlands and water resources management, through the development and implementation of guidance on the joint management of agricultural and wetland systems for food production, poverty reduction, livelihoods support and environmental sustainability" (GAWI, 2006).

The specific purposes of the project are to:

- develop a supporting framework and associated guidelines for the sustainable management of different types of wetland–agriculture systems affected by the full range of water resources, agricultural and wetland policies, systems, and practices;
- build capacity to implement the guidelines;
- promote the use of the guidelines.

Specific areas of the COP8 Resolution that are to be addressed include the need to:

- enhance the positive role that sustainable agricultural practices may have *vis-à-vis* the conservation and wise use of wetlands;

- minimize the adverse impacts of agricultural practices on wetland conservation and sustainable-use goals;
- identify examples based on wetland-type specific needs and priorities that take into account the variety of agricultural systems;
- optimize services of wetlands for livelihoods (agricultural crops and other ecosystem services);
- provide guidance at the practical level that should receive priority, with additional guidance at the policy/planning level.

The GAWI group has identified six work packages:

- knowledge consolidation and guidance,
- guidelines,
- fieldwork,
- outreach and dissemination,
- capacity building,
- project management and public relations.

This present report is within the first work package of “knowledge consolidation and guidance” and has the following specific scope and purpose:

- to apply the drivers, pressures, state changes, impacts and responses (DPSIR) model to analyse cases of agriculture–wetland interaction (AWI);
- to identify the most pertinent issues affecting AWIs around the world;
- to identify the most appropriate responses to these issues/challenges (i.e. to encourage “good practice”),
- to illustrate through the presentation/application of a set of cases that the issues are “real” – i.e. valid to a wide set of biophysical and socio-economic settings.

This report is not a set of guidelines, nor is it a policy brief. Rather, it is a technical framework that is used to:

- scope out the relevance and nature of AWIs;
- identify the range of responses to AWIs that are occurring;
- determine gaps/limitations in current practices and so identify opportunities for comprehensive responses;
- set out the type, methodology and content of the AWI guidelines to be developed.

Overall, it illustrates the benefits and limitations of the proposed framework, concept and method, and meets the objective of scoping AWIs. As a result, the primary audience of the framework document are technical and professional staff, rather than policy-makers and managers.

In this document, the DPSIR model has been used to analyse 90 cases of AWI. The particular focus has been on the need to apply this analytical method to the assessment of AWIs and to identify issues and lessons that can inform future work on the development of guidelines for AWIs.

This report consists of four sections:

- Section 1 discusses AWIs and applies the DPSIR model to the analysis of the 90 cases.
- Section 2 provides examples of how the DPSIR model can be applied, using five cases with different AWIs.
- Section 3 reviews the response data in the light of the need to find specific interventions that can help achieve sustainable wetland use, and suggests ways of moving from this analysis toward guidance, both conceptually and practically.
- Annexes, including details of the case studies.

Section I

Agriculture–wetland interactions

Chapter 1
Exploring agriculture–wetland interactions: a framework for analysis

People have had an intimate association with wetlands from prehistory to the present day. Wetlands such as swamps, marshes and estuaries have been among the most attractive areas in the landscape, satisfying a variety of needs for hunting and gathering, spirituality, water resources and agriculture. However, some wetlands have been sources of disease and other hazards, and this has limited their use. There is evidence that wetland agriculture has made a significant contribution to the well-being of many societies around the globe over the centuries and even millennia. For example, archaeological work in Central America has indicated that Mayan wetland agriculture dates back 3 000 years (Denevan, 1982). Similarly, in Southeast Asia and the Pacific, staple crops that are adapted to wetland conditions have been cultivated and consumed for thousands of years (Bayliss-Smith and Golson, 1992), while more than half of the world's population is supported by rice (CA, 2007). Wetlands of different types (from rivers to coastal lagoons) also provide important areas for various types of fishing or fish culture. Agriculture in the montane bogs of the Andes is reported to have supported food production for 25 million people prior to the arrival of Europeans (Zimmerer, 1991). In Africa, agriculture has long been practised on the floodplains of major rivers, such as the Niger, Zambezi and Nile, and in other types of wetland such as dambos and bas-fonds or inland valley bottoms (Marie, 2000; Gluckman, 1941; Owen *et al*., 1994; IVC/WARDA, 1997). Indeed, wetlands have been, and remain, a critical agricultural resource for people in many parts of the world.

In terms of their benefits to human populations, the importance of wetlands goes beyond agriculture to include a range of other ecological functions and socio-economic benefits. The Millennium Ecosystem Assessment (MA) (2005b) introduced a new classification of these as: provisioning services (e.g. food, water, fibre and fuel); regulating services (e.g. water regulation and purification, erosion control, and climate regulation); cultural services (e.g. spiritual and recreational values); and supporting services (e.g. soil formation and nutrient recycling). These are discussed in more detail below.

In this discussion, wetland agriculture is interpreted in a wide sense to include not only cultivation and other "farming" types of activities (such as grazing) but also aquaculture and other forms of coastal and inland fishing.

Despite the importance of wetlands to society, recent research has drawn attention to a global trend in wetland degradation and destruction as a result of human interaction. According to the MA (2005b), more than 50 percent of specific wetland types in North America, Europe, Australia and New Zealand were lost, converted or degraded during

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the twentieth century. While wetland loss has been a historical process, going back many centuries, it has primarily been driven by agricultural use of these areas, and especially the industrialization of farming with the use of heavy machinery. Wetlands in many areas, especially in the developed world, have been completely drained for crop production, to the extent that they no longer retain any natural wetland characteristics. However, in some areas, less intensive agricultural practices have been implemented, and wetland characteristics have been conserved, albeit in a managed form. For example, in the lowlands of the United Kingdom and northern Europe, water-meadows have been managed as grazing and hay-producing grassland, or fen, with a system of sluices, ditches and embankments used to flood the land with nutrient-rich, silt-laden water (Etherington, 1983). Similarly, throughout Southeast Asia, many traditional rice production systems, especially those that incorporate aquaculture, have effectively and sensitively combined human manipulation of the environment with natural flooding regimes, thereby minimizing environmental degradation.

Throughout the world, population pressure, demand for food, and economic development have driven wetland agriculture and led to the overexploitation and pollution of wetland resources. These drivers of wetland agriculture will probably intensify as the demand for increased economic output and food production is set to grow substantially for the next three decades (CA, 2007). At present, such drivers are likely to be most severe in the developing countries with rapidly developing economies and growing populations. These countries will require the intensification of food production, often in previously marginal or little used areas.

The increased demands on wetlands are accompanied by a global shift towards intensive mono-agriculture. This is leading to the more complete conversion of wetlands to agricultural uses through drainage, water management, and vegetation clearance, with more freshwater being abstracted for irrigation, and a growing propensity for agricultural pollution. In effect, the provisioning services of wetlands are being increasingly exploited at the cost of the regulating, cultural and supporting services. While this is creating benefits for people in terms of food production, there is growing concern about whether or not this is sustainable, given the way regulating and supporting ecosystem services of the wetland environment have been altered or destroyed. Increasingly, it is recognized that these production systems have a negative impact on their natural environment, and on the natural resource base on which they depend.

This recognition of the interconnectedness of these wetland ecosystem services has led to attempts to conserve and rehabilitate wetland areas. For example, recognition of the way that regulating services of wetlands can mitigate flood events has led to the implementation of river basin management plans to restore and conserve wetlands. Moreover, as evidence of the ability of wetlands to purify contaminated water increases, more rehabilitation of existing wetlands and construction of new "artificial" wetlands has taken place (Denny, 1997; Gopal, 1999; Kivaisi, 2001). However, a key challenge for wetland conservation and rehabilitation, which is focused on regulating services, is the need to appreciate the wider socio-economic importance of wetland resources for provisioning services, particularly through wetland agriculture. This has been stressed recently in the CA, which noted the need to pay more attention to how ecosystem services can contribute to agriculture and how agriculture should recognize the need to contribute to ecosystem functioning (CA, 2007).

While attention has been given to the relationship between agriculture and wetlands in parts of the MA (2005b) and the CA (2007) that consider the nature of the challenges faced in balancing the demands on the different ecosystem services provided by wetlands, the GAWI initiative seeks to take this a step further. GAWI seeks to develop guidelines that will help strike a balance in terms of the exploitation of wetland ecosystem services, and achieve sustainability in AWIs. It is intended that the guidelines will effectively manage and reduce the negative impacts associated with productive[1] use of the natural resources base of wetland ecosystems. In addition, GAWI also seeks to identify the ways in which agricultural outputs from such sustainable AWIs can be maintained at levels that are compatible with the needs of society, and contribute to ecosystem use that is sustainable in economic, social and environment ways, whether at the *in situ* or basin level.

The sustainability envisaged by GAWI contains two management/development pathways that need to be explored:

- In selected areas of ecological importance, sustainability can be reached by permitting and stimulating "non-intrusive" productive use of natural resources within the wetland ecosystem, in other words *in situ* agrowetland systems that are non-intrusive in the sense that they are within the resilience and carrying capacity of the ecosystems. In such cases, productive use can be further enhanced by actively and explicitly valuing and rewarding beneficial ecosystem services that have traditionally not been valued and rewarded in the production and food economy (e.g. water regulation and purification, biodiversity, and carbon sequestration).
- At the larger and basin scale, specific trade-offs between provision and regulatory/ nature conservation will be needed. Sustainability at the basin level can be increased by explicit management of the upstream and downstream impacts between production systems and wetland ecosystems, concentrating on minimizing negative impacts and mitigating strategies. This consists of a twin-track approach:
  - altering and managing production systems to minimize negative impacts, while allowing for production (output) maximization;
  - explicit, and conscious, landscape management that utilizes the revitalization and beneficial functioning capacity of natural ecosystems.

There are two other key points to consider in this initial orientation of the GAWI work: (i) valuing wetlands and creating markets for their services; and (ii) focusing on specific wetland–agriculture situations. With respect to the former, it is suggested that there is a need to move beyond the view that wetlands provide or render services, all of which should be valued by society – a view that has dominated conservationist approaches. Rather, it is proposed here that wetlands need to develop markets for their services, and that through these markets the rendering of these services will be stimulated. In other words, the ecosystem services need to be derived by local customers who can accrue concrete benefits. This then stimulates exploration of innovative approaches to identify which services, beyond provisioning ones, can develop markets and provide such concrete benefits.

In terms of the focus of the GAWI work, in the present situation, it can be argued that the biodiversity wetland hot spots are being addressed by Ramsar and its community, while the intensive agricultural use of wetlands is subject to efforts to sustain the productivity of these areas and that agriculture will always be the focus of such sites. Where the GAWI work is most relevant is in the "middle ground", where agriculture is expanding into wetlands. According to the MA, these are the vast majority of "ordinary" wetlands, which are not dedicated to nature conservation or entirely converted to agricultural use already.

WETLANDS – DIVERSITY AND DEFINITION

Definitions and typologies

The definition and classification of wetlands has to be addressed, principally because it facilitates the task of developing management approaches and policy development for

[1] Productive use refers to the economic use and exploitation of provisioning (e.g. agriculture and fisheries), regulating (e.g. hydropower, water purification, etc.) and cultural services (e.g. recreation and tourism). In essence, the exploitation of any or multiple ecosystem services in economic terms.

wetlands. Wetlands are diverse environments; spatially and temporally, but also in terms of physical size, ecology, hydrology and geomorphology. The Ramsar Convention embraced this diversity in a single definition, grouping together a wide variety of landscape units whose ecosystems share the fundamental wetland characteristic of being strongly influenced by water. Since 1971, the Ramsar Convention has considered wetlands to be: "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 metres." (Davis, 1994).

This definition reflects a hydrological perspective with water as the key factor. Other writers have stressed the link between hydrology and biology, and proposed "ecohydrological" definitions, while others have suggested geomor-phological definitions (e.g. Dugan, 1990) or agricultural (crop) definitions (e.g. FAO, 2002 and 1998). Thus, a wide array of wetland definitions are in circulation that are informed by the perspective taken and the primary purpose for which they were defined (e.g. nature/ecosystem conservation, small-scale agricultural development, or hydrological classification).

At times, these different classifications may lead to confusion and misunderstanding as there is no clear overview of how they relate to one another. However, these different approaches to wetlands contain valuable insights and experiences of often specific wetland characteristics, uses and interactions. Here, the choice has been made to adopt the Ramsar classification of wetlands, but with explicit recognition of their wider interactions within the river basins in which they are situated. This analytical approach is equally suited to be adopted on any of the other wetland classifications.

Table 1 presents the Ramsar classification system for wetlands, and illustrates the diversity of wetland types that occur around the globe, focusing on a range

TABLE 1
Categorization by wetland type (Ramsar categories)

Code	Wetland type
	Marine/coastal wetlands
1	Permanent shallow marine waters
2	Marine subtidal aquatic beds
3	Coral reefs
4	Rocky marine shores
5	Sand, shingle or pebble shores
6	Estuarine waters
7	Intertidal mud, sand or salt flats
8	Intertidal marshes
9	Intertidal forested wetlands
10	Coastal brackish/saline lagoons
11	Coastal freshwater lagoons
12	Karst and other subterranean hydrological systems
	Inland wetlands
13	Permanent inland deltas
14	Permanent rivers/streams/creeks
15	Seasonal/intermittent/irregular rivers/streams/creeks
16	Permanent freshwater lakes
17	Seasonal/intermittent freshwater lakes
18	Permanent saline/brackish/alkaline lakes
19	Seasonal/intermittent saline/brackish/alkaline lakes and flats
20	Permanent saline/brackish/alkaline marshes/pools
21	Seasonal/intermittent saline/brackish/alkaline marshes/pools
22	Permanent freshwater marshes/pools
23	Seasonal/intermittent freshwater marshes/pools on inorganic soils
24	Non-forested peatlands;
25	Alpine wetlands
26	Tundra wetlands
27	Shrub-dominated wetlands
28	Freshwater, tree-dominated wetlands
29	Forested peatlands
30	Freshwater springs;
31	Geothermal wetlands
32	Karst and other subterranean hydrological systems
	Human-made wetlands
33	Aquaculture (e.g. fish/shrimp) ponds
34	Ponds
35	Irrigated land
36	Seasonally flooded agricultural land
37	Salt exploitation sites
38	Water storage areas
39	Excavations
40	Wastewater treatment areas
41	Canals and drainage channels, ditches
42	Karst and other subterranean hydrological systems

of characteristics, hydrological, ecological, geomor-phological and economic. This classification has been used as the basis for the analysis and for creating a simplified categorization of the cases in this study identifying: inland flowing, inland still permanent, inland seasonal, inland peat, saline, brackish and human-made (Chapter 2). This is similar to the set of categories used by the MA. (The classification in Figure 1 is slightly different from that of the MA text, although this figure was used in the MA [2005b]).

Global diversity and distribution of wetlands

Recent studies suggest that wetlands occupy in excess of 12.8 million km^2 globally, although this is probably an underestimate as a result of variations in the definitions used for identification (Finlayson *et al.*, 1999). Although wetlands are a common landscape feature across all continents (Figure 1), there is an uneven distribution in specific types. For example, the cool wet climate of the temperate and subarctic zones favours the development of extensive areas of peatland, which arguably account for from one-third to half of the world's wetlands (Mitsch, Mitsch and Turner, 1994). In tropical areas, peatlands are not as widespread, with most located in highland areas that receive abundant rainfall or in specific low-lying areas of Southeast Asia – peat forests (Hughes, 1996). Similarly, mangrove forests are the tropical and subtropical equivalent of temperate saltwater marshes (Hughes, 1992).

ECOSYSTEM SERVICES

Ecosystem services concept

Attitudes towards the value of wetlands have changed significantly in the last 50 years. Throughout much of the developed world, there has been a growing recognition that, rather than being unproductive wastelands in their natural state that benefit from conversion, wetlands are in fact multifunctional natural resources that provide a range of services of inherent value to human well-being (Maltby, 1986; Dugan, 1990; Barbier, Acreman and Knowler, 1997; Roggeri, 1998; Silvius, Oneka and Verhagen, 2000). The Ramsar Convention has made significant progress in highlighting their importance for global biodiversity, and, in recent years, research has drawn attention to the environmental functions and socio-economic benefits that wetlands can provide; what the MA (2005b) terms the "ecosystem services" of wetlands.

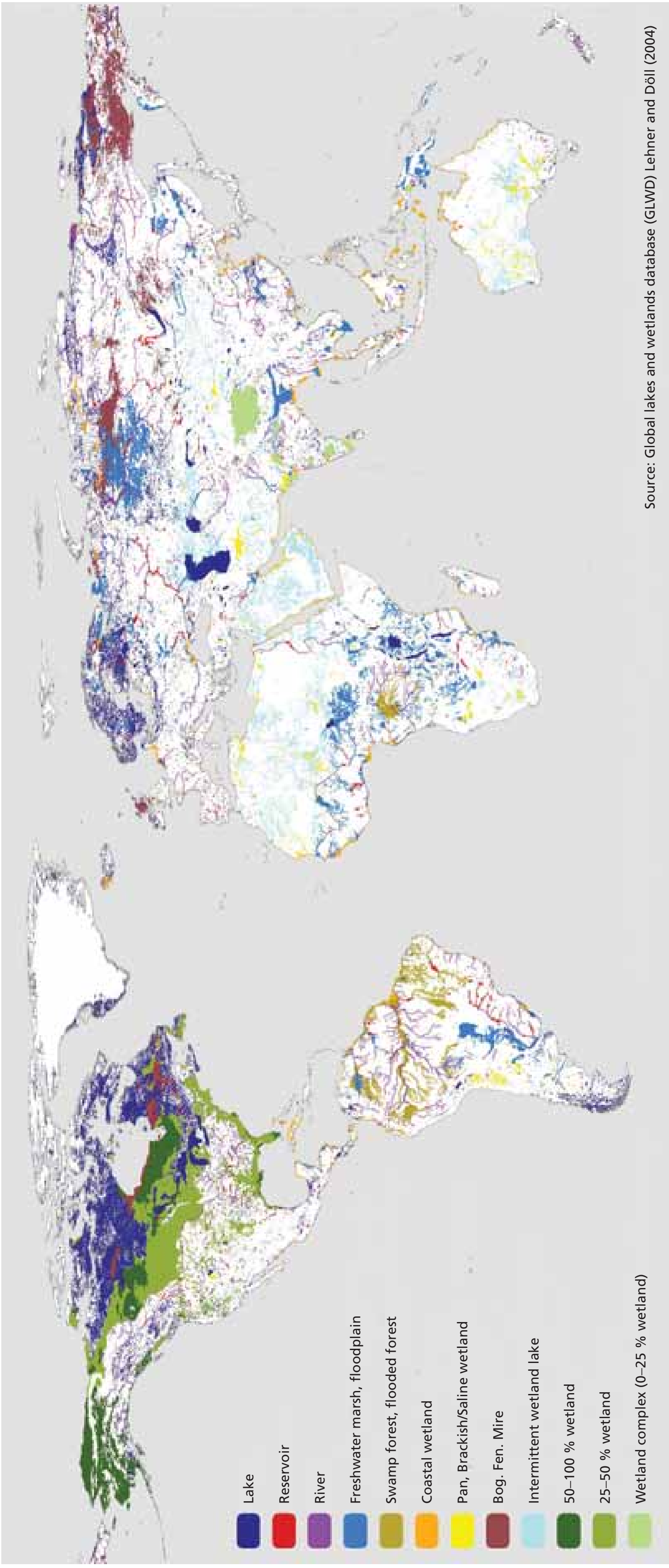
Discussions of the services provided by wetlands are numerous (Adamus and Stockwell, 1983; Maltby, 1986; Dugan, 1990, Barbier, 1993, Roggeri, 1998; MA, 2005b), and considerable research has been carried out on the specific roles wetlands play and how these interact with the local environment. However, despite the wealth of literature, classifications of these services (often called functions and benefits) have rarely been consistent. Hence, the recent MA (2005b) terminology, and its widespread acceptance, is helpful. This uses the term ecosystem services for all wetland functions and benefits, and subdivides these into:

- provisioning (goods produced or provided by ecosystems, e.g. food, fuel and fibre);
- regulating (benefits from the processes of ecosystem regulation, e.g. water partitioning, and climate regulation);
- cultural (non-material benefits from ecosystems, e.g. spiritual, recreational and aesthetic);
- "support" (factors necessary for producing ecosystem services, e.g. hydrological cycle, soil formation, and nutrient cycling).

These are summarized in Table 2 and discussed further below.

The first three categories of services are directly useful or beneficial to humans or human well-being as they provide the primary means for production, natural resources management, and spiritual well-being. The fourth one is distinct in constituting services,

FIGURE 1
Global distribution of wetland types



Source: MA (2005b).

TABLE 2
Ecosystem services provided by, or derived from, wetlands

Services	Comments and examples
Provisioning	
Food	Production of fish, wild game, fruits and grains
Freshwater (a)	Storage and retention of water for domestic, industrial and agricultural use
Fibre and fuel	Production of logs, fuelwood, peat and fodder
Biochemical	Extraction of medicines and other materials from biota
Genetic materials	Genes for resistance to plant pathogens, ornamental species, etc.
Regulating	
Climate regulation	Source of and sink for greenhouse gases; influence local and regional temperature,
	Precipitation, and other climate processes
Water regulation (hydrological flows)	Groundwater recharge/discharge
Water purification and waste treatment	Retention, recovery and removal of excess nutrients and other pollutants
Erosion regulation	Retention of soils and sediments
Natural hazard regulation	Flood control and storm protection
Pollination	Habitat for pollinators
Cultural	
Spiritual and inspirational	Source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems
Recreational	Opportunities for recreational activities
Aesthetic	Many people find beauty or aesthetic value in aspects of wetland ecosystems
Educational	Opportunities for formal and informal education and training
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Nutrient cyclying	Storage, recycling, processing and acquisition of nutrients

(a) While freshwater was treated as a provisioning services within the MA, it is also regarded as a regulating service by various sectors.
Source: MA (2005b).

or natural processes, that are required to maintain the ecosystem and/or have a distinct function in natural resources cycles. This ecosystem concept has received widespread recognition and has been formally adopted by Ramsar as a principal framework for wise use of wetlands.

Not all wetlands support the full range of ecosystem services, and specific services may be associated with specific types of wetland (Table 3). However, the key lesson from this conceptualization is the linkages between different sorts of services and the way in which the support and regulating services are essential for ensuring the continuation of provisioning services.

Provisioning services

The provisioning services provided by wetlands tend to be associated with the direct exploitation of wetland products for economic gain or subsistence.

Crop production

Farming activities are major economic pursuits in and around many wetlands, where crops such as rice, maize, and various vegetables and fruit are cultivated (Dries, 1989; Soerjani, 1992; Omari, 1993). Seasonally inundated floodplains are often particularly important farming resources because they frequently have very fertile soils, with high clay content (which facilitates water retention in the dry season). Various methods have been developed to maximize the use of these areas throughout the seasons, both during the flood period and especially after it has receded (Adams, 1993; Meinzen-Dick and Bakker, 1999).

TABLE 3

Relative magnitude of ecosystem services derived from different inland wetland ecosystems

Services	Perm. & temp. rivers & streams	Perm. lakes & reservoirs	Seasonal lakes, marshes & swamps, including floodplains	Forested wetlands, marshes, & swamps including floodplains	Alpine & tundra wetlands	Springs & oases	Geothermal wetlands	Underground wetlands, including caves and groundwater systems
Inland wetlands								
Provisioning								
Food	high	high	high	high	low	low		
Freshwater	high	high	medium	low	low	low		high
Fibre & fuel	medium	medium	low	high	medium	low	low	
Biochemical products	low	low	not known	not known	not known	not known	not known	not known
Genetic materials	low	low	not known	low	not known	not known	not known	not known
Regulating								
Climate regulation	low	high	low	high	low	low	low	low
Hydrological regimes	high	high	medium	medium	low	low		low
Pollution control & detoxification	high	medium	low	medium	low	low		medium
Erosion protection	medium	low	low	medium	not known	low		low
Natural hazards	medium	high	high	medium	medium	low		low
Cultural								
Spiritual	high	high	medium	medium	low	medium	low	low
Recreational	high	high	medium	low	low	low	low	low
Aesthetic	medium	medium	low	medium	low	low	low	low
Educational	high	high	medium	medium	low	low	low	low
Supporting								
Biodiversity	high	high	medium	medium	low	low	low	low
Soil formation	high	low	medium	high	low	not known	not known	
Nutrient cycling	high	high	high	high	low	low	not known	low

Note: Blank cells indicate that the service is not considered applicable to the wetland type.
Source: MA (2005b).

Fishing

Fish production is a basic element in the economy of many wetlands. There is often a localized economic and nutritional dependence on this resource as fish provide a crucial source of protein. In addition, in recent decades, fish farming (aquaculture) has been developed in coastal brackish lagoons in several parts of the tropics (DeMerona, 1992; Bwathondi and Mwamsojo, 1993; Primavera, 1995; Ocampo-Thomason, 2006).

Livestock grazing

Seasonal wetlands can provide a valuable resource for livestock grazing as a result of the high biomass associated with these areas. Sometimes, these are grazed directly, but in other cases they are used for hay production. In many of Africa's savannahs where the climate is semi-arid and rainfall is seasonal, wetland grazing is widespread (Scoones, 1991), with wetland landforms, such as the dambos of Zimbabwe, the fadama of Nigeria and the floodplains of Niger and Zambia, being important seasonal grazing resources (Roberts, 1988; Turner, 1994).

Water supply and hydropower

Most wetlands can provide a potable supply of water for the surrounding population (either directly or from springs). This is a critical function in many semi-arid or seasonally dry areas (Scoones, 1991). Depending on their ecohydrological characteristics, wetlands may be able to purify water supplies as a result of the effects of microbial action. The ability of a wetland to regulate and store water can also be beneficial in the production of hydroelectric power by moderating and thereby improving the flow of supply of water for power production, and there are many human-made wetlands created for this purpose. However, in the tropics, wetlands are often seen to compete for water owing to high evaporation rates.

Production of fibre, fuel, and medicinal and dietary supplements

Natural wetland plants can be used for a variety of purposes from construction to medicine. Soerjani (1992) points out that 70 percent of the 266 species of weeds associated with wetland rice cultivation in Indonesia can be utilized in a range of activities including medicine, cattle fodder, household uses and for human consumption. On Lake Tana in Ethiopia, locally harvested papyrus has been used in the construction of fishing boats for hundreds of years (Muthuri, 1993).

Agrobiodiversity as a provisioning service

Biodiversity[2] is discussed below under cultural services. However, from an agricultural perspective, agrobiodiversity created by human management on and around farmlands, may have crucial provisioning services to provide to farming systems. Specifically, services such as pollination, harbouring natural predators of agricultural pests (integrated pest management [IPM]), and hatching and breeding for fish are found in wetlands. Indeed, these niches may be created through some agricultural use of wetlands. However, conversely, some pests may also be harboured and supported in this way. In terms of land use and the ecosystem, the important element here is that enough diversity is maintained to provide adequate niches or agrobiodiversity refuges, i.e. provide "agricultural off-season" refuges for species that thrive within crop systems (or seasonal fishing grounds). From the ecological perspective, agrobiodiversity refuges can be considered supporting services to the ecosystem. Thus, in an ecosystems management approach, the conscious management of agrobiodiversity refuges can be expected to be an important element.

Regulating services

Depending on their specific ecohydrological and geomorphological characteristics, wetlands are able to provide a diversity of services that play a key role in the regulation and stability of the physical environment.

Climate regulation – biosphere and microclimate stabilization

The conditions of high humidity and evapotranspiration found in many wetlands may affect local and regional climates significantly (Roggeri, 1998). In addition, the process of microbial decomposition is encouraged in wetland ecosystems. This can lead to storage of carbon or emissions of gaseous by-products (including methane), which may have implications for global atmospheric stability (Odum, 1979). While the destruction

[2] Biodiversity contributes to all of the ecosystem services depending on the perspective from which it is viewed and the service which is focused on. Products of biodiversity include many of the provisioning services provided by ecosystems (such as food and genetic resources). In this case, specific economic benefits are obtained from the contribution to integrated pest management (IPM). In cultural services, biodiversity is valued for its intrinsic and aesthetic sake. In regulating services, biodiversity in the form of plants helps regulate flows. In the case of supporting services, biodiversity is part of the functioning of the natural wetland ecosystem.

of wetlands results in the release of carbon into the atmosphere, the extent to which wetlands actively mitigate carbon dioxide (CO_2) emissions through photosynthesis remains unclear and the subject of ongoing research.

Water regulation – flood control and river regulation
Wetlands are able to mitigate floods by storing potential floodwaters, reducing floodwater peaks, and ensuring that the floodwaters from tributaries do not all reach the main river at the same time (Maltby, 1986). During the dry season, subsurface flow from wetlands may replenish stream flow. However, there is increased evidence that wetlands vary considerably in their capacity for water storage and for dry-season flow maintenance and that these capacities are dynamic during the seasons and with rainfall conditions (Bullock and Acreman, 2003).

Water regulation – water table recharge and discharge
When the velocity of water entering a wetland is reduced and its subsequent residence time in the wetland increases, there may be some percolation of the water downwards into the aquifer, and, consequently, water table recharge occurs (Mihayo, 1993). As a result of their lowland position in relation to surrounding land, many wetlands also act as sinks for water discharged from aquifers (Roggeri, 1998). However, the relationship between groundwater and wetlands is extremely complex and dependent on many factors, such as regional groundwater flows, geology, hydraulic conductivity, and the slope and relief of the catchment (Carter and Novitski, 1988).

Water purification – maintaining water quality
The practice of discharging wastewater into natural wetlands has been used as a means of waste disposal for hundreds of years (McEldowney, Hardman and Waite, 1993). Research on the ability of wetlands to purify water has shown that anaerobic conditions, which exist within wetlands, enhance the retention of many compounds and facilitate processes such as denitrification, ammonification and the formation of insoluble phosphorous–metal complexes (Bastian and Benforado, 1988). Wetland vegetation, such as *Eichhornia crassipes,* is able to store large quantities of nutrients and heavy metals (Gopal, 1987). Paddy rice fields also seem able to act as a sink for synthetic agrochemical pollutants.

Erosion regulation – sediment trapping
As the velocity of water decreases on entering a wetland, suspended sediment settles. Destruction of wetlands can seriously affect this process and lead to downstream sedimentation. However, the buildup of sediment in a wetland also causes its waterholding capacity to deteriorate and can change its vegetation, soil characteristics and agricultural productivity.

Not all the above regulating services are provided to the same degree in each wetland. In many cases, it is difficult to identify precisely the extent of the service and the value that can be put on it (Bullock and Acreman, 2003). It is suggested that the following qualifications need to be considered, as part of a general recognition of the site-specific nature of these regulating services, although the degree to which these qualifications apply is also debated:

- Water table recharge and discharge: Infrequent and very difficult to quantify; natural wetlands are most likely to occur in natural depressions in the landscape with low permeable soils and/or high water tables.
- Flood control and river regulation: Very site-specific, and exploitable mostly with respect to urban centres.
- Sediment trapping: Common in floodplains and deltas; in other wetlands, it is too complex to measure positive impacts.

- Water purification and maintenance of water quality: Most likely and most valuable – in terms of being manageable and economically exploitable, although it can be variable.
- Biosphere and microclimate stabilization: Limited, except for mist rain forests; too complex and difficult to be exploitable.

Cultural services

Cultural services include aesthetic, educational, spiritual, biodiversity and recreational values. They contribute to human well-being via the direct economic benefits of their exploitation (e.g. tourism), and their psychosocial value.

Spiritual and inspirational

There are many examples of cultures around the world where wetlands or water have a spiritual significance. For example, for the Bantu-speaking peoples of Southern Africa, water sources and riparian zones have sacred status through their association with water spirits (Bernard, 2003). For the Maori in New Zealand, water has its own life-force (mauri), for which people are obligated to have a duty of care (Williams, 2006).

Aesthetic value

In many parts of the world, there is a growing recognition of the importance of wetlands as major wildlife habitats, which offer significant potential for tourism. In Zimbabwe and Zambia in particular, wetland tourism is being developed as a component of a wider rural development programme in that local communities are given the responsibility of managing wetlands for their aesthetic and other benefits (such as game and sport fish). In return, they receive economic and social benefits from tourism (Chabwela, 1992; Sanyanga, 1994; Barbier, Acreman and Knowler, 1997; Duim and Henkens, 2007).

Biodiversity

Wetlands are host to a rich species biodiversity because they offer a range of ecological niches for wildlife both spatially and temporally (Maltby, 1986; Denny, 1994). In seasonally inundated wetlands, different species have adapted to conditions during the dry season and the wet season. In permanent wetlands, species may have evolved in ecological isolation and may represent an endemic and rare population (Turner, 1988). Dugan (1993) presents a variety of specialized plant adaptations to wetland environments. These include *Sphagnum* spp., which is tolerant of the extreme acidic conditions found in some marshes, and a range of aquatic and emergent plants including *Cyperus papyrus*, *Pistia stratiotes* (water lettuce) and *Eichhornia crassipes* (water hyacinth). In addition, many areas of wetland support high concentrations of endemic fauna. For example, the Bangweulu basin in Zambia provides a habitat for 30 000 black lechwe antelope (*Kobus lece smithemani*) and it constitutes one of Africa's most important areas for sitatunga (*Tragelaphus spekei*). Wetlands provide vital habitats for migratory waterbirds – a factor that served as the impetus for the Ramsar Convention.

Supporting services

These services refer to the key processes or factors necessary for maintaining the ecosystem services provided by wetlands. They include the major environmental cycles involved with hydrology, nutrient flows and soil formation. The key point is that these services are the essential underpinning of the wetland ecosystem services. If disrupted, they will affect the services that wetlands can provide. Specifically for agriculture, if these support services are disrupted, then the provisioning services through wetland agriculture will be adversely affected with reduced yields and sustainability will be undermined. Extreme examples are salinization and loss of water through gully formation.

This discussion confirms the wide range of ecosystem services obtained from wetlands. It shows the value that can be obtained locally, at the basin level and globally, and the potential for the generation and sustaining of livelihood benefits / provisioning services, directly and indirectly. It also confirms the point made above about the way in which these services are interlinked and all involved in supporting human well-being.

However, despite the importance of wetlands, recent research has argued that the ecohydrological relationships and socio-economic process in many wetlands remain poorly understood (Bullock and Acreman, 2003; Woodhouse, Bernstein and Hume, 2000) (Table 3). Therefore, it is important to exercise caution when generalizing about the services performed by wetlands, and also the socio-economic benefits that emanate from them. A key criticism of global wetlands policy to date has been the popularization of universal wetland values as a means of justifying and promoting wetland preservation (Bullock and Acreman, 2003). In reality, there is a need for a combination of approaches with a more site-by-site approach, with sensitivity to the biophysical and socio-economic diversity. Greater understanding of specific ecosystem services is needed if they are going to be promised in return for wetland protection and payments.

Application and relevance of the ecosystem service concept to the GAWI initiative

The concept of "ecosystem services" is particularly pertinent to the GAWI initiative in that most AWIs can be characterized by their use of, or effect on, provisioning, regulating, cultural and supporting services. Therefore, a key task of AWI analysis is to identify the linkages and interactions between the various ecosystem services, and to determine those whose services are mutually supportive, or incompatible. An understanding of these relationships is central to the development of sustainable wetland–agriculture systems.

As outlined below, the MA (2005b) regards the balanced use of diverse wetland ecosystem services as synonymous with sustainable utilization. This draws on a well-established body of literature that regards diversity among ecosystems as central to ecological resilience, i.e. the capacity to withstand shocks and pressures (Adger, 2000). Any AWI that relies heavily on the overdevelopment of a single provisioning service may facilitate degradation in the resource base, this being seen in the reduced capacity to perform one or more services. While maintaining a diversity of ecosystem services is important for wetland sustainability, a key challenge for the GAWI project is to identify how this balance is to be obtained and made compatible with agricultural activities, and with the increasing global demand for food.

WETLAND CHANGE DYNAMICS

Wetland formation and loss under natural conditions

Wetlands are areas whose formation is influenced by ecological, hydrological and geomorpohological processes. As these underlying processes are extremely dynamic, so too are the wetlands. As transitional zones between dryland and waterbodies, wetlands are continuously evolving in response to local ecohydrological processes.

Many wetlands experience gradual change and form slowly through the accumulation of water and sediments, and the partial decomposition of plant material. Others are ephemeral in nature, occurring only in response to seasonal rainfall. Some wetlands represent one stage in the succession from a standing waterbody to a terrestrial environment, which can occur over decades or millennia (depending on wetland size and sedimentation processes). Wetland formation and succession is a natural process – by no means is all wetland change caused by anthropogenic influences. Hence, in studying AWIs, this dimension needs to be kept in mind.

Global change in wetlands, patterns and rates

It is widely accepted that wetlands are degrading at an unprecedented rate, vastly beyond that of natural loss, yet there are few reliable accounts of the current situation. The MA (2005b) reports that more than 50 percent of specific types of wetlands in parts of North America, Europe, Australia and New Zealand were converted for agriculture during the twentieth century. However, for elsewhere, many estimates are speculative. Infrastructure and urban expansion have also led to the loss of some wetland areas. A recent global assessment of 227 major river basins showed that 37 percent were affected by fragmentation and altered flows, potentially indicative of wetland loss (MA, 2005b). However, loss of coastal wetlands is better established. The MA (2005b) reports that 35 percent of the world's mangrove forests (for which data exist) have disappeared within the last two decades owing to aquaculture development (mostly for shrimp and prawn production).

However, there are also some gains in wetland areas as a result of water management, especially through the extension of rice cultivation beyond existing wetlands, and to a lesser degree through reservoir formation, seepage from dams and irrigation systems, and the rehabilitation of former wetlands (this mainly for recreation, cultural or biodiversity conservation or flood management, primarily in high-income countries). However, in many of these cases, especially with rice production, the full range of ecosystem services is not developed. The growing interest in artificially constructed wetlands for wastewater treatment has also led to gains in wetland area in most parts of the world (Gopal, 1999; Kivaisi, 2001).

Key driving forces – their diversity globally and by wetland type

The underlying causes of global wetland degradation and loss are complex and diverse, and ultimately vary from one location to another, and between wetland types. Although it is dangerous to generalize, some lessons and trends can be drawn from empirical research around the world. In many developing countries for example, the partial or full conversion of wetlands for subsistence agriculture may represent a direct response to population pressure, which in turn is linked to poverty. Globally, wetland conversion for agriculture is likely to be economically motivated and linked more intrinsically to regional or global markets. The trend towards wetland rehabilitation in the developed world has also been driven by the recognition of the value of wetlands for recreation, conservation and flood protection.

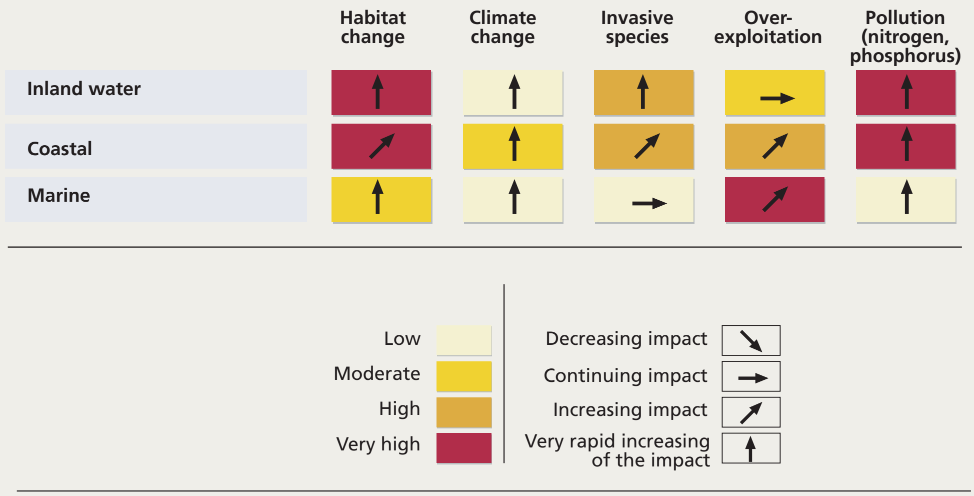
In an analysis of the key driving forces behind wetland loss and destruction, the MA (2005b) draws a distinction between inland and coastal wetland systems, and differentiates between indirect and direct drivers of change. It suggests that the primary indirect drivers (termed "drivers" in this study) of wetland loss in inland wetlands have been population growth and increasing economic development. These have influenced the direct drivers (termed "pressures" in this study), which are more conspicuous and include: infrastructure development; land conversion (to agriculture); water withdrawal; pollution; overexploitation of plants, land and fish; and the introduction of alien species. For coastal wetlands, such as saltwater marshes, mangroves and coral reefs, population growth and economic development are again cited as the key indirect drivers of change. Conversion to other land uses, the diversion of freshwater flows, nitrogen loading, overharvesting, and siltation have constituted the major direct drivers of wetland destruction. Figure 2 gives some indication of the relationship between direct driving forces or pressures on different wetland types in the context of impacts on biodiversity.

AGRICULTURE AND WETLAND INTERACTIONS

In examining the relationship between wetlands and agriculture, it is useful to distinguish between *in situ* interactions (where there is direct agricultural intervention

FIGURE 2
Main direct drivers of change (pressures) in wetland systems

The cell colour indicates the impact of each driver on biodiversity in each type of ecosystem over the past 50–100 years. High impact means that over the last century the particular diver has significantly altered biodiversity in that ecosystem; low impact indicates that it has had little influence on biodiversity in the ecosystem. The arrows indicate the trend in the driver. Horizontal arrows indicate a continuation of the current level of impact; diagonal and vertical arrows indicate progressively stronger increasing trends in impact. Thus, for example, if an ecosystem had experienced a moderate impact of a particular driver in the past century (such as the impact of overexploitation in inland water systems), a horizontal arrow indicates that this moderate impact is likely to continue. This Figures is based on expert opinion consistent with and based on the analysis of drivers of change in the various chapters of the assessment report of the MA Condition and Trends Working Group. The Figures presents global impacts and trends that may be different from those in specific regions.



Source: MA (2005b).

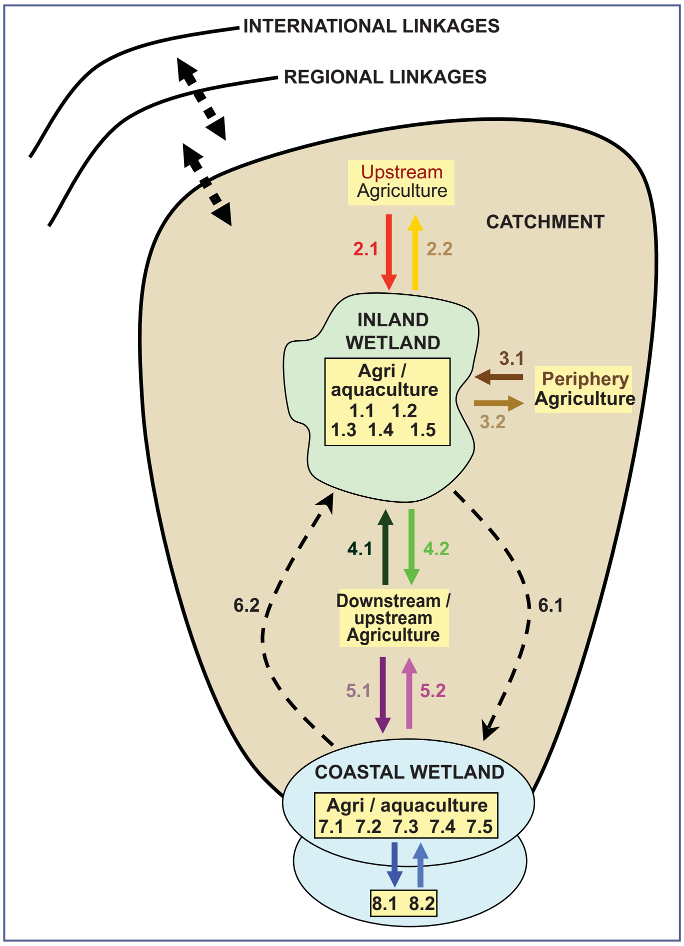
within wetlands) and external interactions (where the effects of external [upstream, downstream or peripheral] agricultural activities affect the wetland and its ecosystem services). These relationships are presented in Figure 3, which shows the linkages through a basin, from the headwaters areas, via wetlands at any stage in the basin, to coastal wetlands. In addition, there can be several inland wetlands in a river basin, or coastal wetlands adjoining one another. Hence, individual wetlands should not be seen in isolation, as they are usually linked to others within the river basin system. The nature of the interactions highlighted can be of various types: environmental – where drainage occurs; socio-economic – where livelihoods are affected; and political – where conflicts are stimulated.

In situ interactions

In situ interactions, represented by 1.1 to 1.4 in Figure 3, involve on-site wetland agricultural activities. They can be characterized by the complete (1.1) or partial (1.2) transformation of wetlands to agricultural use, which usually alters the regulating services of wetlands. Agricultural transformation includes a range of practices that create pressures on the wetland ecosystem, such as drainage, the application of fertilizers and pesticides, and livestock grazing. Examples are the seasonal cropping of floodplains in West Africa, the cultivation of upland peat bogs in the Andes, and the drainage of floodplain marshes in Europe for arable land use or livestock grazing. There is a clear transformation of wetland ecohydrology in these cases as a result of these interactions.

In situ interactions can also include agricultural exploitation that does not transform the wetland environment or have any impact on available ecosystem services (1.3). This

FIGURE 3
Conceptual model of agriculture–wetland interactions



Key:

1. Wetland agriculture (*in situ*) interactions
   - 1.1 Complete transformation of wetland ecosystem to agricultural use
   - 1.2 Partial transformation of wetland ecosystem to agricultural use
   - 1.3 Agricultural use of wetlands without transformation of ecosystem (e.g. limited/ sustainable ecoagriculture).
   - 1.4 Enhancement of wetlands / creation of additional wetlands (often used for agriculture)
   - 1.5 Reversion to natural wetland
2. Upstream agricultural activity (external) interactions (from distant catchment)
   - 2.1 Upstream agricultural activity influencing wetland ecosystem and wetland agriculture downstream
   - 2.2 Wetland ecosystem influencing upstream agricultural activity
3. Periphery agricultural activity (external) interactions (from local catchment)
   - 3.1 Periphery agricultural activity influencing wetland ecosystem (e.g. irrigation water, fringe drainage)
   - 3.2 Wetland ecosystem influencing periphery agricultural activity (e.g. flooding)
4. Downstream agricultural activity (external) interactions
   - 4.1 Downstream agricultural activity (including wetland agric) influencing wetland upstream (or wetland agriculture upstream)
   - 4.2 Wetland ecosystem influencing downstream agricultural activity (e.g. flooding, constant supply of water, water purification)
5. Coastal-upstream agricultural activity (external) interactions
   - 5.1 Influence of immediately upstream (wetlands and non-wetland agriculture) on coastal wetland
   - 5.2 Influence of coastal wetland on upstream non-wetland agricultural activity
6. Coastal wetland – inland wetland (external) interactions
   - 6.1 Influence of inland wetland (natural or altered by agriculture) on coastal wetland
   - 6.2 Direct influence of coastal wetland (natural or altered by agriculture) on inland wetland
7. Coastal wetland agriculture (*in situ*) interactions
   - 7.1 Complete transformation of wetland ecosystem to agricultural use
   - 7.2 Partial transformation of wetland ecosystem to agricultural use
   - 7.3 Agricultural use of wetlands without transformation of ecosystem (e.g. limited/sustainable ecoagriculture).
   - 7.4 Enhancement of wetlands / creation of additional wetlands
   - 7.5 Reversion to natural wetland
8. Coastal wetland agriculture / aquaculture – other coastal wetlands (external) interactions
   - 8.1 Influence of adjacent / upstream coastal wetlands
   - 8.2 Coastal wetland aquaculture / agriculture influencing adjacent coastal wetland functioning

Regional linkages = Groundwater resources, microclimates, shared wildlife resources (including birds), population, ethnic groups, culture, agricultural and conservation policies, etc.

International linkages = same, but next scale up.

is most commonly seen in fishing where this involves “harvesting” in a sustainable manner. Other non-agricultural services of this sort include the gathering of reeds and plant materials. These sustainable harvesting activities are the typical “wise uses” of wetlands as defined by the Ramsar Secretariat. In addition, some wetlands have been manipulated to create “artificially” constructed wetland environments for agricultural and aquaculture purposes (such as rice paddy fields and fish ponds) and water storage for irrigation. In such cases, there may be the enhancement of wetlands or the creation of additional ones (1.4). Another scenario is one where wetland agriculture occurs at a level that does not disturb the wetland ecohydrology or ecosystem services (1.3). It may be characterized by ecoagricultural practices, where, for example, crops that are well adapted to the wetland environment are cultivated in an environmentally sensitive manner. An example is the multicropping and agroforestry practices in the *Terminalia* wetland forests in Micronesia (Drew *et al*., 2005). Similarly, the management of water-meadows in Europe does little to disturb wetland ecohydrological conditions. A third case is on the upper Zambezi floodplain, where the scale of the annual flood and groundwater flows into the floodplain is so great and the areas of cultivation so limited at present that there is little or no alteration in the ecosystem services.

The above discussion has focused on inland situations, but it could also refer to coastal wetlands with similar interactions owing to aquaculture or, to a lesser degree, crop production. Figure 3 also shows such *in situ* interactions within coastal wetlands – lagoons or mangrove swamps (7.1–7.4).

Because of the ecohydrological requirements of crops, it is typically inland wetlands that are more susceptible to direct agricultural interactions. Swamps, marshes, floodplains and bogs, in particular, are an important source of water and fertile soil in semi-arid areas. Hence, they constitute attractive agricultural resources. In more temperate areas where the soil moisture in wetlands is perceived to be more of a problem rather than a resource, such wetlands are more likely to undergo intensive drainage. Coastal lagoons in the tropics have also been particularly attractive in the last three decades because of various types of aquaculture and fish pond development.

External interactions (basin interactions)

External interactions between agricultural/aquaculture activity and wetlands are represented by interactions 2–6 in Figure 3. They are typically interactions between the wetland ecosystem and agricultural/aquaculture activities that are external to the wetland itself (upstream, downstream or on the periphery of wetlands).

Upstream agriculture–wetland interactions

Wetlands are most frequently influenced by upstream agricultural activity (2.1, 5.1 and 6.1). A typical example is where upstream agriculture results in the diversion of water, which affects the quality and flow of water entering a wetland ecosystem. This may be associated with dam development or irrigation. Poor agricultural practices in the upland areas may also lead to soil erosion and sedimentation or the runoff of agricultural waste, both of which can affect wetlands. The subsequent pressures may lead to the degradation of that wetland and a reduction in its ability to perform certain ecosystem services. If that wetland is itself directly transformed by agriculture within it (see above), this agriculture may also be affected. An example of this relationship is the case of an upstream dam and irrigation development influencing people’s wetland-dependent livelihoods downstream in the inner delta of the Niger River (Zwarts *et al*., 2005).

Alternatively, there is the possibility of wetlands (either in a natural state or themselves directly transformed by agriculture) influencing agricultural activity upstream (2.2, 5.2 and 6.2). An example is where wetlands contribute to the overall reduction in velocity of river flow, and their capacity to store water and retain sediment causes upstream waterlogging that may affect agricultural activity. This may also lead to the extension of the wetland if this flooding is prolonged, as is the case in the Sorou Valley in Mali (Woodhouse, Bernstein and Hulme, 2000). Further, as in the case of the Usangu plains in the United Republic of Tanzania, conservation of downstream wetlands may lead to increased agricultural pressures on the limited resource base upstream, as provisioning services, such grazing, can no longer be used in the downstream wetland.

Periphery agriculture–wetland interactions

The interactions of wetlands with peripheral agriculture (3.1 and 3.2) are arguably similar. Wetlands in their natural state, or those directly transformed by agriculture, can affect agriculture in adjoining, neighbouring and peripheral areas through the regulation of the water table and accommodation of runoff. Similarly, peripheral agriculture can induce change in the natural wetland ecosystem, or influence wetland agriculture itself, in the same way as upstream agriculture. A similar series of scenarios could exist for coastal wetlands (8.1 and 8.2).

Downstream agriculture–wetland interactions

Wetlands can also play an important role in downstream agricultural activities (4.1). A key function of some wetlands is their ability to store water and regulate river flows. This has clear implications for the productivity of downstream agriculture. The direct use of a wetland for agriculture results in the alteration of its water regulation function, and can also have implications for downstream agriculture. Downstream agricultural activity (4.2), such as water extraction for irrigation, may alter the hydraulic gradient and result in the more rapid release of water from wetlands upstream, lowering the level of the water table. Similarly, downstream agriculture reliant on the extraction of water from upstream wetlands (either through gravity or mechanical means) will also tend to induce change.

These types of interactions also occur with respect to coastal wetlands (5.1 and 5.2). For example, agriculture in upstream areas may influence the functioning of coastal wetland environments such as estuaries and mangrove forests (5.1) through sediment deposition and hydrological changes, while the reverse interaction also occurs owing to features such as saline influxes when freshwater flows are very low due to irrigation extraction.

Some interactions from inland wetlands onto coastal wetlands may also be identified (6.1), with the reverse (6.2) being more hypothetical.

These AWIs typically occur in chains that go beyond a single wetland and its immediate catchment to include the whole river basin. For example, upstream agriculture reducing the flow of water to a wetland may indirectly affect further downstream agricultural activities. All wetlands are susceptible to this catchment-wide nature of external AWIs. These can become international in nature in some cases where human or animal populations, as well as water, move long distances.

Nature of agriculture–wetland interactions

While most of the above discussion has focused on the environmental nature of these interactions between agriculture and wetlands, all the linkages discussed above (in Figure 3) can also have a socio-economic and political dimension. For example, in considering the interaction between a wetland ecosystem and upstream agricultural activity that reduces stream flow and produces polluted runoff, both the impacts and the areas where responses are required are likely to be socio-economic and political, as well as environmental (physical, chemical and biological):

- Environmental impacts and responses: transformation of wetland ecosystem or wetland agriculture (pollution, desiccation, reduction in biodiversity, or hydrological change); overall change in regulating ecosystem services available.

- Socio-economic impacts and responses: reduction or increase in wetland provisioning services for local people; reduction or increase in some aspects of livelihood security; wider impacts on local markets.
- Political impacts and responses: creation of conflict between different interest groups (see below); local mobilization to influence upstream agricultural practices and policy; upstream agricultural policy may change (via a feedback loop).

This has considerable significance in terms of the subsequent analysis of AWIs, pointing to the need to take a wider view than is often the case with site-specific studies of environmentalists.

Relevance for the GAWI project

Recognition of the different interactions that occur between agriculture and wetlands confirms the emphasis that the GAWI project has to place on functional linkages, be they of an ecological, economic, social or political nature. Moreover, in the study of AWIs, two major types of interactions need to be explored: (i) those within wetlands; and (ii) those between wetlands and other parts of the functioning system, usually the river basin.

MA AND CA PERSPECTIVES ON WETLANDS AND AGRICULTURE

Millennium Ecosystem Assessment (MA)

The MA recognizes that, with respect to inland wetlands, agricultural development has historically been the principle cause of wetland degradation worldwide. It reports (MA, 2005b) that, by 1985, between 56 and 65 percent of inland water systems had been drained for intensive agriculture in Europe and North America (27 percent in Asia and 6 percent in South America). Other agriculture-related developments are also reported to have had their impacts, including the building of irrigation dams (which have disrupted river flows and flooded or drained wetland areas), the diversion of water from wetland areas for irrigated agriculture, and the destruction of mangroves for shrimp culture. Moreover, poor agricultural practices, rather than agriculture per se, such as polluted agricultural runoff and erosion that leads to sedimentation, have led to the damage or loss of wetlands through biodiversity loss and the rapid succession to dryland environments.

However, the MA notes that, while most agricultural activities in and around wetland ecosystems fundamentally alter their structure and functioning (affecting the ecosystem services that wetlands can provide), agriculture in wetlands (in the widest sense as used here) has made a positive contribution to society. In many countries, the socio-economic benefits associated with wetland agriculture are often significant in terms of agricultural output, livelihoods, poverty reduction and trade. In other words, the reduction in regulating, cultural and support services is “compensated” for by increased provisioning services.

In considering various scenarios for the future of wetlands, the MA (2005b) predicts an increase in wetland degradation and wetland conversion to agricultural land in the next 50 years, with these trends being exacerbated by the likelihood of climate change. Specifically, population growth and the need for food production will place increasing demands on the provisioning and regulating services of wetlands, while the actual capacity of wetlands to provide these services will decrease. In particular, the MA notes that the overdevelopment of provisioning services can damage regulating and support services, which in turn can feed back and undermine provisioning services.

The MA proposes that, in order to address this situation both today and in the future, it is necessary to try to move from the presently skewed or imbalanced use of ecosystem services that occurs in many AWI situations and achieve a more balanced use of the services. This will require appropriate valuing of these services. In particular, the MA suggests the need to pursue a more equitable balance in the use of wetland ecosystem services, thereby reducing the pressure on wetlands from provisioning services alone and enhancing the regulating and support services so as to achieve more ecologically balanced and functioning wetland and river basin systems.

The view is presented that, while agriculture inevitably has some impact on wetland ecosystems and their regulating services, agriculture does not necessarily lead to complete wetland degradation and loss, with a range of regulating services retained (albeit reduced or altered). Conversely, it notes that a level of support and regulating services is critical for the maintenance of provisioning services. In addition, it shows that there can also be positive impacts from agricultural development in terms of biodiversity, such as that supported by irrigation tanks in Sri Lanka or by irrigation scheme wastewater lakes in California, the United States of America, which support migratory birds (Meinzen-Dick and Bakker, 1999).

With this perspective, the MA suggests the need to explore the issue of trade-offs between different wetland ecosystem services in wetland management policy. However, it also recognizes that in the wider context of the Millennium Development Goals (MDGs), climate change mitigation strategies, and the commitments under the Ramsar Convention, there may be a need to address the issue of trade-offs between different ecosystem services (e.g. a reduction in agricultural use in exchange for maintaining water provision) in order to fulfil the specific needs of various wetland stakeholders. This implies a new skewed use of ecosystem services (over time and in space) to meet MDG goals with negative impacts on wetlands and their ecosystem services. At the same time, the MA also advocates the use of "ecosystem approaches" to wetlands management and planning that focus on managing environmental resources and human needs across landscapes; in other words, balancing trade-offs at a level beyond the wetland alone.

Comprehensive Assessment of Water Management in Agriculture (CA)

The recent Comprehensive Assessment of Water Management in Agriculture, published in 2007 (CA, 2007), drew attention to the emergence of competition for water resources between agriculture and natural ecosystems. In the context of a growing population with increasing food demands (doubling in the next 50 years) and the uncertainties of climate change, the assessment argues the need for more efficient and equitable water management in agriculture, in support of the MDG, especially given the fact that 850 million people remain undernourished at present. The question framing the CA was "How can water for food be developed and managed to: help end poverty and hunger; ensure environmentally sustainable water–agriculture practices; and find the balance between food and environmental security?"

The fact that the CA is informed by the MA is clear from the environmental points in this framing question and from the focus in one of its eight Policy Actions, which includes obtaining more ecosystem services from agriculture.

However, the CA takes a more detailed look at the situation. Rather than talking in generalities about the balancing of ecosystem services, it focuses on the provisioning services and makes specific recommendations in this area. These include:

- pursuing water-efficient strategies in agriculture as an important means of ensuring the supply to other stakeholders via the services of water-dependent ecosystems and the maintenance of environmental flows;
- seeking multiple-use and multifunctional agricultural systems;
- managing agriculture for diversity in the landscape;
- paying the poor for environmental services provided;
- addressing policies outside agriculture that have major impacts.

The importance of the CA to wetland management is evident in Policy Action 3, which discusses the management of agriculture to enhance ecosystem services, and recognizes that food production in many parts of the world has a negative or degrading impact on biodiversity and ecosystem services. This has implications for human well-being in terms of livelihood sustainability. In response, the CA suggests:

- promoting services beyond the production of food, fibre and animal products in agro-ecosystems;
- making adaptations to agro-ecosystems to cope with the uncertainties of environmental change;
- incorporating, in land and water management, an understanding of the importance of biodiversity in supporting ecosystem services;
- recognizing the importance of diversity in land and water management, and ecosystem services, in promoting resilience and sustainability;
- raising awareness of the role and value of ecosystem services;
- improving inventories and assessments of ecosystem services, and their environmental thresholds with respect to service provision and agriculture.

As in the MA, the CA advocates the adoption of integrated approaches to managing land, water and ecosystems; ones that recognize and incorporate diversity within the landscape. Wetlands constitute an important landscape unit with the potential for facilitating multiple stakeholder benefits, and environmental and livelihood security. However, in order to achieve these, more attention needs to be given to how ecosystem services can contribute to agriculture, and to how agriculture should be sensitive to and support ecosystem functioning.

Conclusions for the GAWI initiative

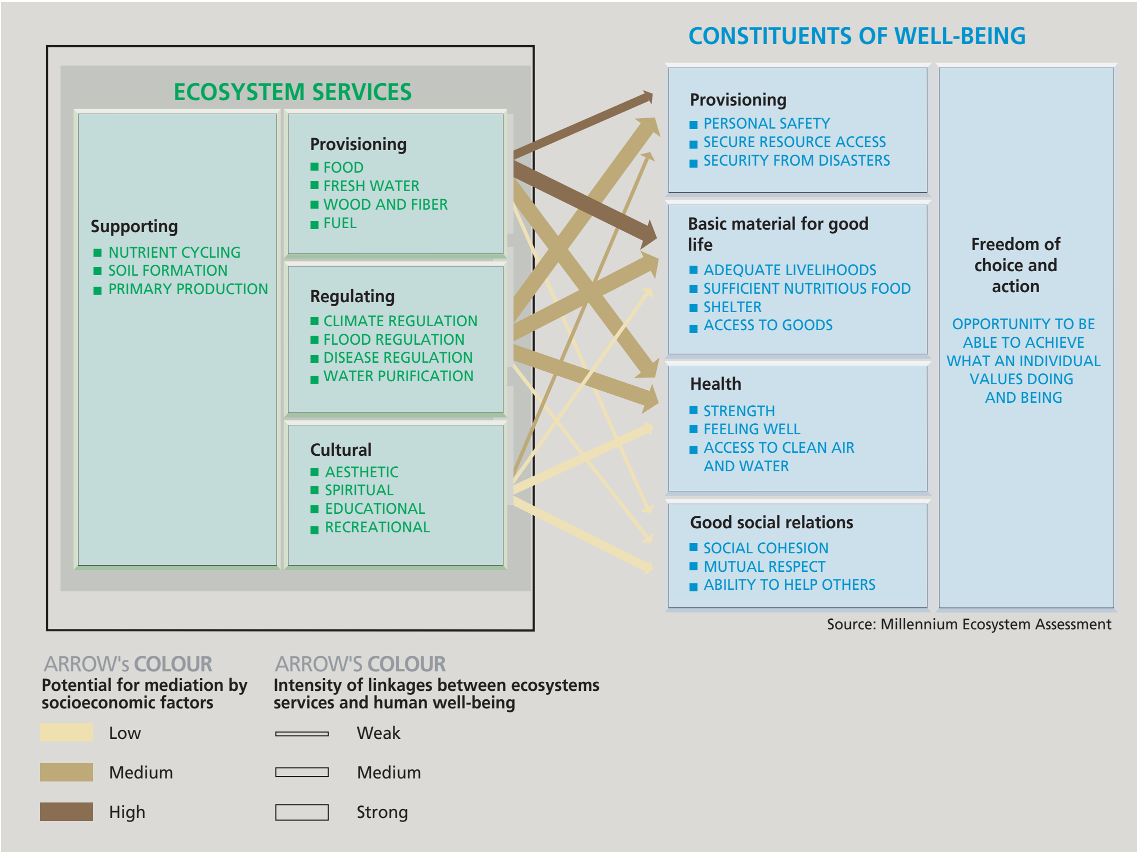
Overall, this discussion shows that increasing economic and population pressures have been the major driving forces in the predominantly human-induced transformation of wetlands. The drive to increase economic output and food production, in particular, has led to production systems in wetlands that depend on excessive emphasis of the provisioning services at the expense of the regulating services (in the MA view), and excessive water use (in terms of the CA). This has led to wetland degradation and to situations where water resources in a river basin are overallocated (closed basins – CA terminology) and where environment flows are inadequate for wetlands. The MA stresses that a rebalancing of the ecosystem services is needed in order to sustain the productivity of these areas. However, this balance could be increasingly difficult to achieve because of some of the other priorities of governments, such as the poverty reduction goals of the MDGs. The CA focuses on the provisioning services and the need to make these more ecologically sensitive, with attention to agro-ecological opportunities, multiple-cropping systems, and achieving diversity within agricultural landscapes.

Together, the MA and CA provide vital guidance for the GAWI work, drawing attention to different concepts and scales of analysis, including the ecosystem services, the functioning of river basins as a whole, multiple uses in agro-ecosystems, and the landscape scale of management. Overall, it can be concluded that the focus for the GAWI project must be on applying an ecosystems approach to agriculture, and a productive services approach to ecosystems in order to achieve a more environmentally friendly agriculture, and a productively-oriented natural environment, rather than a pure agricultural landscape.

LIVELIHOODS, POVERTY REDUCTION AND WETLAND STAKEHOLDERS

As the MA and CA point out, the pressures on wetlands are growing, and new ways of thinking are needed in order to address the issues involved in AWIs. The need for such innovations is especially important given the role of wetlands in the developing world and their contributions to livelihoods through subsistence and domestic market production and through their contribution to exports. In understanding this situation, it is necessary to identify the pressures that are being put on wetlands, their origins, and the actors involved in managing these areas.

FIGURE 4
Ecosystem services and human well-being



Source: MA (2005a).

Livelihoods and poverty reduction

Wetlands are important in the development process as they can contribute in several ways to the MDGs – through food security, water and sanitation and the ecologically sustainable use of natural resources (Figure 4). The MA reformulates the MDGs into a well-being concept and identifies four areas where ecosystem services can contribute: security, material well-being, health, and social relations. Despite growing pressures on wetlands for agriculture, it is necessary to try to maintain these multiple benefits and to ensure their availability across the socio-economic spectrum.

However, access to these ecosystem services is not equitable, and wetland agricultural development often leads to winners and losers, with conflicts and marginalization resulting. For example, large-scale commercial agriculture has often appropriated open-access wetlands for estate production, with the positive provisioning outputs being offset by negative effects not just on regulating ecosystem services but on previous users of the area (Bondestam, 1974). Smaller-scale use of wetlands also raises many debates about the socio-economic implications, with pre-existing low-intensity users of wetlands losing out to those who seek to develop these sites for intensive farming. For some wetland farmers, use of these areas is a survival strategy or a lifeline (Silvius, Oneka and Verhagen, 2000) with wetlands seen as marginal areas. For others, wetlands offer an opportunity for enhancing an accumulation strategy, and these are far from peripheral and difficult areas to use given the resources they have. The different perspectives of the various groups seeking livelihood and other benefits need to be given due consideration in understanding AWIs.

Local-level stakeholders

At the community level, there are diverse interest groups, reflecting the involvement of different people in wetlands in different ways, as well as their varying socio-economic and political influences. Differentiation in society is increased through interactions with wetlands; with the poor, in some areas, using them for survival with limited success, while the rich mobilize resources successfully to use these areas in response to market opportunities (Woodhouse, Bernstein and Hulme, 2000). In other cases, local government is interested in appropriating wetlands for its own uses, sometime to address population pressure and land shortages (Rwanda), or to provide opportunities for investors and estate agriculture (Ethiopia) (Bondestam, 1974).

National-level stakeholders

At the national level, one regularly finds entrenched sectoral views of wetlands from the different lines, ministries and agencies. Sometimes, there is competition between government agencies as they pursue their specific interests and responsibilities for water, agriculture, biodiversity, hydropower, etc. National economic development goals often tended to dominate and win out in the competition for national resources and political support, so that food security and export earning were pursued through national water policies that failed to take a holistic view of wetland ecosystem services. While there is still evidence of this in several countries, with political pressures leading to an emphasis on short-term goals and policies (Dries, 1991), there is also growing recognition of the need for greater sensitivity to environmental considerations and the need to strike a balance, or reach a trade-off, between different ecosystem services. The precise methods for achieving this remain subject to much discussion and have few examples of successful practice.

International community and wetlands

At the level of the international community, there is a range of stakeholders interested in wetlands, from those that focus on agricultural production to those that focus on conservation. Some of these international organizations focus on the provisioning services from wetlands because of their interest in benefits for local communities, national food security, and poverty reduction. Depending on their sensitivity to the other ecosystem services of wetlands and their recognition of the importance of wetland regulating services in order to maintain provisioning services, these organizations may focus on sustainable use rather than purely on agricultural production.

In recent years, there has been increased recognition among most of the international organizations concerned in some way with wetlands about the value of wetland ecosystem services and the need to achieve some consensus with other perspectives in order to take forward their specific interests. This is seen especially on the conservation side, where the need for inclusion of human development needs (especially addressing poverty) has grown. It is also seen in the areas of development where the need to maintain water flows for environmental purposes (including the maintenance of wetland ecosystem services) and the functioning of hydrological systems are increasingly recognized.

Relevance to the GAWI initiative

The GAWI initiative has to consider its task with reference to the current development priorities outlined in the MDGs, especially the eradication of extreme poverty and hunger (MDG 1) and ensuring environmental sustainability (MDG 7). Wetlands are potential contributors to development goals in many ways and, hence, there is a need to enhance their functioning as multiple-use resources, providing a range of ecosystem services that meet these goals and improve livelihoods. To achieve this, there is a need to understand and engage with the actors involved in order to address the dynamics of AWIs and the different environmental and socio-economic consequences.

CONCLUSIONS

This chapter confirms the complexity of the AWI situation. There is diversity in terms of the wetlands and the ecosystem services they provide. There is a wide range of different ways in which agriculture and wetlands can interact, both spatially and in terms of their characteristics – ecological, socio-economic and political. Finally, there is a range of actors involved in AWIs, operating at different scales and with different interests. This complex situation suggests that any analysis will require a clear framework and a rigorous approach. Chapter 2 addresses this issue.