Convention on Wetlands

Ramsar

Wetlands and agriculture: impacts of farming practices and pathways to sustainability

Purpose

This Briefing Note aims to support policy makers and practitioners to implement more sustainable agricultural practices to ensure the wise use of wetlands. It calls for an integrated approach across the agriculture, water and wetland management sectors to avoid further wetland degradation while providing food security.

Background

Resolution XIII.19 on Sustainable agriculture in wetlands requested that the Scientific and Technical Review Panel (STRP) of the Convention on Wetlands compile and review information on positive and negative impacts of agricultural practices on wetlands. The STRP 2019-2021 work plan adopted at the 57th meeting of the Standing Committee identified Task 1.2 on sustainable agriculture and wetlands as a high priority. This Briefing Note presents scientific and technical information of agricultural impacts on wetlands; the corresponding Policy Brief 6 provides analysis and recommendations for policy makers.

Transformation of agricultural practices and systems is needed to reverse the trend of wetland loss and degradation, while simultaneously providing food for the increasing human population and maintaining adequate food production in a time of rapid environmental change. Wetlands are part of the agricultural system – they provide water for crops, livestock and aquaculture, habitat for rice production and pond fisheries and help to regulate the environment. Wetlands, however, are also subject to significant pressure from agriculture as a result of land conversion, excessive use of nutrients and pesticides, non-sustainable extraction or diversion of water, and over-exploitation of biodiversity.

This briefing note summarises current global knowledge on wetland-agriculture interactions and draws attention to case studies that provide positive examples of efforts to transition to wise use of wetlands as a contribution to more sustainable agriculture. It calls for immediate action to address the most pressing issues facing wetlands – particularly through dialogue between the wetland and agriculture sectors.

Flooded savanna and forests of the Bita River Wetland of International Importance, Colombia.

Relevant Documents of the Convention

Policy Brief 6. *Transforming agriculture to sustain wetlands and people*

Resolution XIII. 19 on *Sustainable agriculture in wetlands*

Resolution VIII. 34 on *Agriculture, wetlands and water resource management*

Resolution X. 31 on *Enhancing biodiversity in rice paddies as wetland systems*

Resolution XI. 15 on *Agriculture-wetland interactions: rice paddy and pest control*

Policy Brief 2. *Integrating multiple wetland values into decision making.*

Fact Sheet 7 on *Wetlands: Source of sustainable livelihoods*

World Wetlands Day 2014 leaflet on *Wetlands & Agriculture: Partners for Growth*

Wetlands and the SDGs: *Scaling up wetland conservation, wise use and restoration to achieve the Sustainable Development Goals*

Key messages

- **Expansion and intensification of agriculture is occurring in many regions to meet growing food demand**. During the past 100 years, crop and grazing lands increased from 27.2 to 46.5% of the world's total land area.
- **Wetlands, including many Wetlands of International Impotance, are being destroyed by agriculture**. The extent of natural wetlands has declined by 35% since 1970 in areas for which data is available, while human-made wetlands, including rice paddy fields and reservoirs, increased by 233%. Agricultural development is a primary cause of wetland loss through drainage and infilling.
- **Remaining wetlands are also impacted**. Over the past 20 years, the intensification of agriculture has led to increased extraction and diversion of water for irrigation and mounting pollution due to a rising global trend in fertilizer and pesticide use.
- **Knowledge of the interactions between different agricultural systems (intensive, extensive, integrated) and inland, coastal and human-made wetlands is needed** to improve environmental policies relating to use of water, fertilizers and pesticides; land management; and to guide on-ground initiatives to promote sustainable agriculture.
- **Sustainable agriculture should not damage the ecological character of wetlands**. By definition, sustainable agriculture "*conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable*". This is consistent with maintaining the ecological character of wetlands and ensuring their wise use as defined by the Convention on Wetlands.
- **Transformation to sustainable agriculture is urgently required to reverse the ongoing trend of environmental degradation and to respond to climate change.** This should include more efficient use of natural resources and reduced pressure on wetlands, through better policies, institutional change, and support for the adoption of sustainable farming. Case studies in this Briefing Note illustrate how these changes can be achieved.
- **Productive dialogue and implementation of cross-sectoral approaches is needed** to adapt agricultural practices and systems, jointly develop wetland-agricultural sector action plans, and provide financing mechanisms.

Introduction

Agriculture continues to be a primary driver of wetland loss and degradation. Across Europe, the Americas, Oceania, Asia and Africa wetlands have been, and continue to be converted to agricultural land to support people's livelihoods and for economic development (UNCCD, 2017).

Wetlands contribute to global food security by supporting agriculture and providing livelihoods, as a source of water for crops and livestock, and as habitat for rice production and aquaculture, helping to meet the world's Sustainable Development Goals (SDGs) (FAO, 2019).

The interactions between wetlands and agriculture take many forms. To understand these interactions, it is important to distinguish between different types of wetland and agriculture systems. Some types of farming systems are inherently more efficient than others in the way they extract biota and use water and nutrients to produce food, which influences their impact on wetlands. To ensure the wise use of wetlands in line with the Convention on Wetlands, and to deliver on the 2030 agenda for sustainable development and the UN Sustainable Development Goals (SDGs), there is a need to share knowledge on the impacts of agriculture on wetlands, improve recognition of the importance of healthy wetlands for agriculture, and identify pathways to transform agriculture.

Livestock and wild herbivores grazing, Pantanal wetland, Brazil.

Definitions

"Agriculture" is the deliberate effort to cultivate crops and/or raise livestock for sustenance or economic gain, and includes fisheries, marine products, forestry and primary forestry products[1]. For the purposes of this Briefing Note the focus is on livestock, cropping and aquaculture based agricultural systems.

"Wetlands" as defined by the Convention on Wetlands are: "*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*".

1 See Basic Texts of the Food and Agriculture Organization of the United Nations at http://www.fao.org/docrep/meeting/022/K8024E.pdf

Global extent and status of agriculture

Agriculture is fundamental to the survival of people, and its existence depends on water. Agriculture extends over 4.8 billion hectares (ha) of the global land surface, with Asia, Africa, and Latin America having the largest areas of agricultural land use (Table 1). Small farms (< 2 ha), mostly in developing countries, account for the greatest number of agricultural producers, but increasingly total land use is dominated by larger, often corporate-based, farms (Lowder *et al.* 2016) that benefit from access to new technology and markets through trade agreements.

The agricultural revolution has been generally successful in feeding people given global population increases, although critical food shortages remain (GRFC, 2019). However, development of agriculture was built on an increased use of resources, particularly water and agrochemicals (fertilizers and pesticides). Many high yielding crop, livestock or aquaculture farms cannot be productive without irrigation and other inputs and in the absence of these inputs yields are often lower than from traditional practices (e.g., Verhoeven & Setter, 2010).

Intensification of agriculture is increasing in many countries, including in India and China, which is leading to increasing diversions of water for irrigation and sustained high applications of agro-chemicals (FAO, 2011; FAO/IWMI, 2018; FAO 2020). Land conversion of natural forests, grasslands and wetlands for intensive and extensive agriculture is also ongoing in many countries (UNCCD, 2017).

Table 1. Extent of agriculture in regions of the world

Continent	Land area (10^3 km^2)			Main crops (area harvested)[4]
	Total[1]	Agri-cultural[2]	Crops[3]	
Africa	30,319	11,395	2,788	Maize, millet, sorghum
Asia	31,999	16,679	5,886	Rice, wheat, maize
Europe	23,330	4,629	2,885	Wheat, barley, sunflower
Latin America & Caribbean	20,525	7,092	1,733	Soybean, maize, sugar cane
North America	20,126	4,635	1,988	Soybean, maize, wheat
Oceania	8,561	3,848	334	Wheat, barley, rapeseed
Total	**134,860**	**48,278**	**15,613**	

Notes: All data derived from FAOSTAT (2020), all definitions according to the respective data source.
[1]Area total: Total land area per continent.
2Agricultural land: the combined area of cropland and permanent pasture and meadows, including rangeland, permanently used for livestock grazing.
[3]Cropland: The area given represents the total harvested area per continent. As cropland defined is land occupied by either permanent or temporary crops (e.g. perennials and annuals), temporary pastures and meadows and land left temporarily fallow. In case one and the same parcel is used twice a year it was counted twice, tree crops are also included but the area may be an estimate, using typical planting density conversion, for some countries were only number of trees was reported. For cereals, only crops for dry grain were considered, crops harvested for hay, silage, feed or grazing are excluded.
[4]Main crops: Main crops in terms of area harvested (ha) per continent.

Wetlands support agriculture and people

Wetland ecosystems as defined by the Convention on Wetlands include inland, coastal/marine and human-made wetlands and are estimated to cover an area of more than 1.5 billion ha (Davidson & Finlayson 2018). They provide many ecosystem services to humanity. Inland wetlands have been estimated to provide, on average, over $USD 25,000 per hectare per year of services (De Groot *et al.*, 2012).

Wetlands contribute directly to agricultural production, providing food for people and a water source for crops, aquaculture, and livestock. Human-made wetlands, including wet pasture, ponds and rice paddies are particularly important for providing staple foods (rice, fish) for many people around the world (FAO, 2019). Review of the Ramsar Site Information Service (RSIS) indicates more than 50% of Wetlands of International Importance provide sustenance for humans, and around 37% provide livestock fodder (Figure 1).

Wetlands further support agriculture by ecosystem regulation, for example, by controlling agricultural pests, recharging groundwater, nutrient cycling and carbon sequestration (Millennium Ecosystem Assessment 2005, Verhoeven & Setter 2010). Data on the regulating and supporting services of Wetlands of International Importance indicates approximately 49% of sites[1] provide flood control or flood storage and 21% of sites facilitate the cycling of nutrients (Figure 1).

Notes:
* Data extracted from the RSIS database October 2019. Analysis utilises RIS data from 2015 onwards (n=567 Wetlands of International Importance) and omits earlier data that was incomplete or submitted in an earlier RIS format.
** the 54% of Wetlands of International Importance that provide sustenance for humans includes wetlands that provide wild food resources, including capture fisheries.

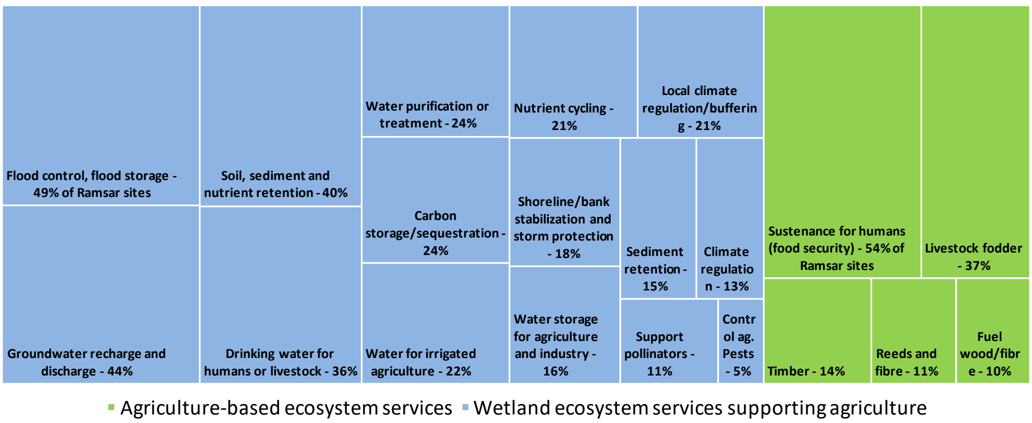


Figure 1.
Ecosystem services and agriculture at Wetlands of International Importance*. The percentage (%) of Sites that i) support agriculture by helping to regulate the environment (wetland ecosystem services supporting agriculture and ii) provide sustenance** or crops from harvest (agriculture-based ecosystem services).

1 Based on analysis of RIS data from 2015 to November 2019 (n=567 Wetlands of International Importance) that omits earlier data that was incomplete or submitted in an earlier RIS format

Agricultural threats to Wetlands of International Importance

Wetlands of International Importance are recognised for their contribution to the conservation of global biodiversity. But many Wetlands of International Importance are under pressure from agricultural practices. Review of Ramsar Information Sheet (RIS) data indicates that agriculture-related practices are or are likely to be having a negative effect on more than 50% of Wetlands of International Importance designated or with data updated since 2015.

The RIS data indicates agricultural practices occurring near Wetlands of International Importance are contributing to wetland degradation in several ways (Figure 2). For example, more than 20% of the world's Wetlands of International Importance are affected by dams, and 20% by drainage. Although not all water infrastructure is built to support agriculture, water extraction and diversion is one of the major causes of wetland degradation. More than 20% of Wetlands of International Importance are also affected by livestock farming, agricultural and forestry effluents or land conversion (Figure 2).

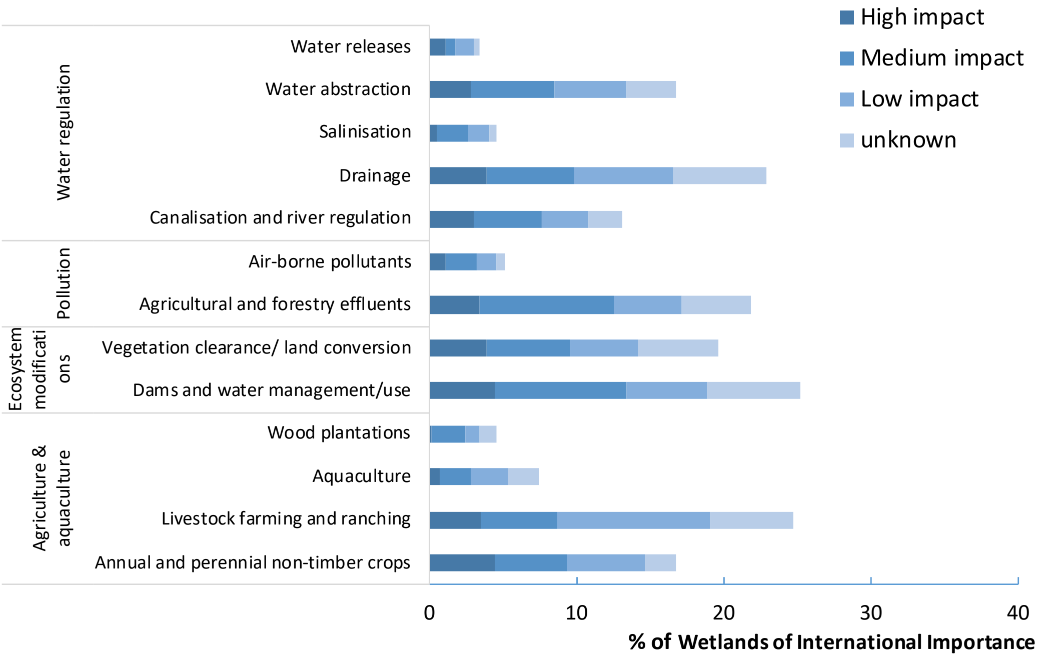


Figure 2.
Agricultural threats on Wetlands of International Importance*. The percentage (%) of Wetlands of International Importance negatively affected by agricultural practices (threats).

Notes:
* Data extracted from the RSIS database October 2019. Analysis utilises RIS data from 2015 onwards (n=567 Wetlands of International Importance) and omits earlier data that was incomplete or submitted in an earlier RIS format.

A global classification of agricultural systems

"Agriculture" represents a wide variety of plant cultivation and animal husbandry systems that occur across the globe depending on bio-geophysical characteristics, cultural and socio-economic factors.

Transitioning towards agricultural sustainability benefits from an understanding of how agricultural systems interact with inland, coastal and human-made wetlands, through defining agriculture types based on the dominant *production system* (agricultural practices), and the level of *resource use* (intensive or extensive).

A global classification of nine agricultural systems (Table 2) helps evaluate agriculture-wetland interactions at global, regional and national scales.

Table 2. Global classification of agricultural systems for evaluating agriculture-wetland interactions.

Production system	Agricultural system	Key defining features
Cropping and livestock	**A.** Rainfed cropping and livestock - extensive	Extensive rainfed systems are typically mixed crop and livestock farms located in upland or arid zones or in sub-tropical and tropical lowland areas. In dry areas, cereal crops like maize, millet and sorghum are produced. In upland and lowland areas, a variety of crops can be found. This farming system includes smallholder farms in developing countries with low inputs of fertilizer, pesticides, improved seeds and compound feeds that produce food for subsistence and local markets.
	B. Rainfed cropping and livestock - intensive	Intensive rainfed systems are common in temperate climate zones with sufficient rainfall and good soil quality like Europe, North America and New Zealand, but also in (sub)tropical areas in South Africa, Brazil, Eastern China, and India. Production is high with optimal cultivation practices, high inputs of fertilizer, feeds and agro-chemicals and farm mechanization. Crops consist of monocrops of wheat, maize, barley, soybeans, rapeseed, sugar beet and potatoes (temperate zone), fruits, rice and oil crops (sub-tropics), or maize, rice, sugarcane and soybeans (tropics). They are often commercial, producing for national or international markets.
Irrigated cropping	**C**. Irrigated cropping	Irrigated croplands represent 25% of the total cropped area in the world with large areas in Asia, North Africa and parts of Australia, North America and Europe. Crop types include a wide variety, including cereals (rice, maize, wheat) and cash crops and fruits (cotton, almonds, palm oil). In Asia, 70-85% of irrigated land is used for the production of cereals, particularly rice. Since 1950, the global irrigated area has more than doubled. Inputs of agricultural chemicals (nutrients, pesticides) are high.
Horticulture	**D**. Horticulture	Horticulture is a high-precision form of irrigated croplands but with distinctive differences in nutrient and water management. Horticulture produces fruits, vegetables and ornamental plants (including flowers), both outdoors and in indoor systems (including glass houses). In indoor systems, fertilizer and water use can be optimised. Horticulture systems often discharge water that is high in nutrients and chemicals. Peat harvested from wetlands is still a widely used for horticulture.
Livestock	**E**. Livestock - extensive	Extensive livestock systems are based on grazing in areas that have too variable or insufficient rainfall, too low temperatures, or unsuitable terrain for cultivating crops. They occur in Central and East Asia, Central and East Africa, and the highlands of Europe, the Middle East, North Africa and South America. Animals include traditional cattle breeds, sheep, goats and other ruminants (e.g. reindeer) capable of digesting natural high-fibre vegetation, and traditionally often herded by nomadic people. In some areas, wetlands provide a seasonal source of grazing. Extensive livestock systems are under pressure because of decreasing grazing areas, increasing livestock densities or conversion to crop land.
	F. Livestock - intensive	Intensive livestock systems are either mixed crop-livestock with intensively managed pasture (mainly cattle), or landless industrial livestock production (mainly pigs and poultry). Intensive pasture produces meat, dairy and other products and is common in North and South America, Australia and Europe and uses genetically improved breeds, supplementary feeds and veterinary support. Landless systems produce pigs (meat) and poultry (meat, eggs) and can be located anywhere as long as they are well-connected to a supply of feed, locally or imported. Cultivation of animal feed crops affects natural ecosystems, e.g. through deforestation or grassland or wetland conversion.
Aquaculture	**G**. Aquaculture - extensive	Extensive aquaculture encompasses non-feed ponds and enclosure systems (cages or pens) or other small-scale/non-intensive fisheries, and coastal seaweed and shellfish culture. This agricultural system utilises wetlands, making use of aquatic resources to support production. Extensive pond aquaculture production traditionally occurs in small-scale farms in Asia, and in central Europe. Coastal seaweed and shellfish systems occur globally.
	H. Aquaculture - intensive	Intensive aquaculture includes ponds, pen or cage systems with feeds, water replacement, aeration, pharmaceuticals and filtration or other technology to increase productivity. In intensive pond systems, nutrients accumulate in pond sediments. Cage and pen systems discharge nutrients into surface water. This system type includes intensive fish and shrimp ponds (mostly in Asia), and cage culture of salmonids (mostly in Norway, Scotland and Chile), of seabream and seabass (Mediterranean); and marine finfish species (particularly in Asia).
Integrated	**I**. Integrated agriculture	Integrated systems combine multiple farming components to enable efficient use of resources. Outputs from one component, which may otherwise be wasted, become inputs to other components resulting in a greater productivity from the same land/water area. Integrated systems are diverse, have relatively low external inputs and maximize the recycling of nutrients and water. Various forms of integrated crop/livestock/fish systems exist, such as integrated irrigation- aquaculture (e.g. stocking fish in canals), inter-cropping (planting more than one crop in same field), agroecology/regenerative agriculture that foster a higher agricultural and natural biodiversity with relatively low external inputs. In many regions intensification of farming has reduced integration and led to mono-cropping, with the loss of traditional practices.

Sources: Tivy (1990); FAO (2011a); Lewandovsky (2018); FAO (2016, 2018b, 2018c); and FAO/IWMI (2018). Annex 1 provides further details on the characteristics of the nine agricultural systems.

How agricultural systems interact with wetlands

Agricultural practices and systems interact with wetlands in many ways. At catchment and river-basin scales agriculture can have delayed interactions with wetlands through system-wide changes in water use, sediment movement, changes in biota and increased pollutants, leading to an overall degradation at landscape scale. Impacts also occur at the wetland-scale, directly by land conversion, water extraction, drainage, nutrient inputs, erosion, soil degradation and harvest of biota.

All these interactions can lead to changes in the ecological character of a wetland and the possible permanent loss of its benefits to people, emphasizing the need for sustainable agriculture (Wood & van Halsema, 2008).

Land conversion

During the 20th century, the use of the earth's land surface by humans has expanded dramatically. The proportion of natural land decreased from 70.1 to 46.5%. At the same time, crop and grazing lands increased from 27.2 to 46.5% of total land area (UNCCD, 2017). The current global extent of wetlands is estimated at between 1.5-1.6 billion ha (Davidson & Finlayson 2018). Due to land conversion, the extent of natural wetlands declined by 35% between 1970-2015, where data exist, while human-made wetlands, including rice paddy fields and reservoirs, increased by +233% (Darrah *et al.* 2019). The rate of decline of natural wetlands during the same period (-0.78% per year) was more than three times higher than natural forests (-0.24% per year), and by 2015, global rates of wetland loss increased to -1.6% (Darrah *et al.* 2019). The proportion of wetland loss attributable to agriculture has not been calculated globally. However, various studies indicate that agricultural development is often the primary cause of wetland loss (e.g. Mao *et al.* 2018; Patino & Estupinan-Suarez 2016; Robertson *et al.* 2019).

Wetland conversion for agriculture also causes greenhouse gas emissions and climate change. Globally, wetlands form only about 5-8% of the land surface but hold about 30% of the total soil carbon store, with peat wetlands and coastal wetlands being particularly important for carbon storage (UNCCD, 2017; Moomaw *et al*, 2018; Ramsar Convention on Wetlands, 2018). Drainage of wetlands for agricultural development causes soil oxidation and major greenhouse gas (GHG) emissions, as well as lost capacity for continued carbon sequestration and storage (Moomaw *et al.* 2018). This is particularly important for wetland types that store large amounts of carbon, such as peatlands and forested wetlands.

Contaminants - Nutrients, Fertilizers and Pesticides

Water pollution is caused by excessive fertilizer use, application of pesticides, salinization from agricultural drainage water and contamination by animal manure and slurries (FAO/IWMI, 2018). Fertilizer use increased steadily around the globe in the period 1960-1990, with the largest growth rates in consumption in Asia, Latin America and Africa. After 1990 this growth has slowed down, especially in Europe and North America. In the developing countries the growth continued but at a slower rate. Total use (consumption) of fertilizer is now about 109 and 41 million tonnes of N and P, respectively, with Asia consuming roughly half of that. Fertilizer use in the other regions is much lower (Figure 3).

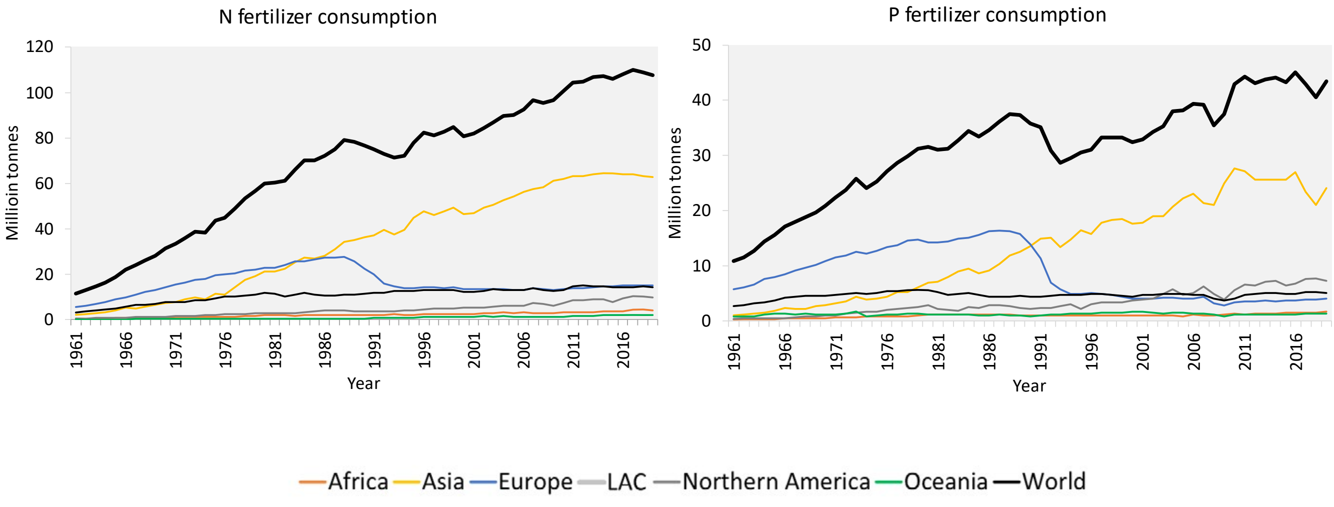
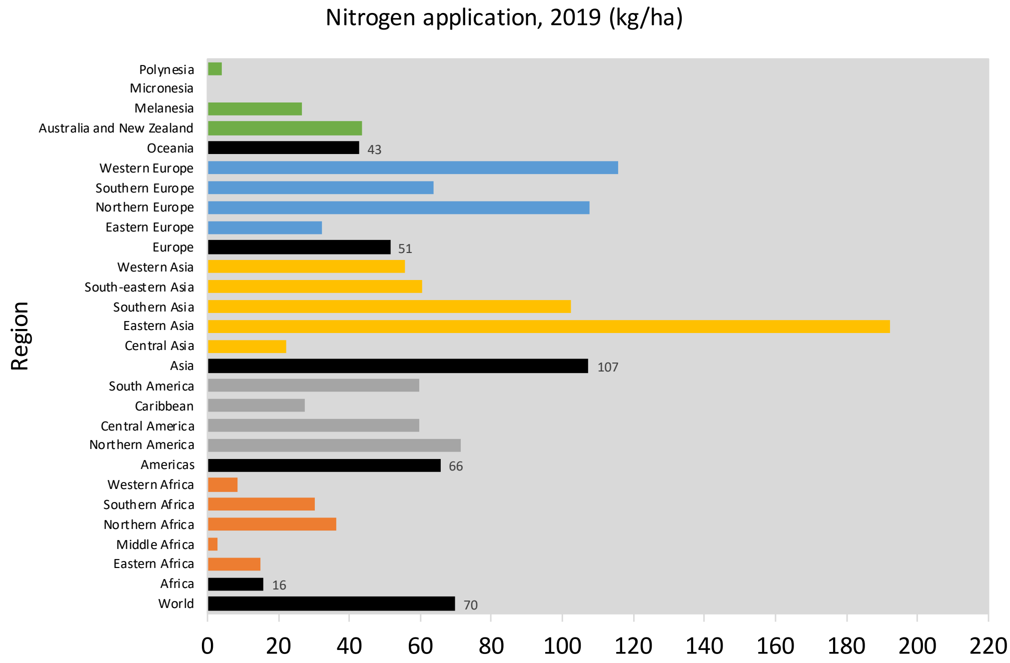


Figure 3.
Global trends in nitrogen (N) and phosphorus (P) fertilizer use. Source: FAOSTAT

High use of fertilizer within or near wetlands increases surface water and groundwater inputs of nitrogen and phosphorus to wetland ecosystems resulting in nutrient enrichment that can have significant ecological effects, including eutrophication, increased productivity of invasive species, higher rates of nutrient leaching and shifts in species composition (Verhoeven *et al*. 2006).

The application rate of fertilizers (kg/ha) also increased, to a global average of 70 kg/ha of nitrogen and 26 kg/ha of phosphorus in 2018. There are large regional differences, with the highest application rates in eastern and southern Asia and northern and western Europe, and the lowest in western, central and eastern Africa and in central Asia (Figure 4). In some regions, nutrient use efficiency has the potential to be improved through the adoption of agroecology/regenerative agriculture practices (FAO, 2018b; Lal, 2020) or other low input agricultural practices (Wu & Ma 2015).



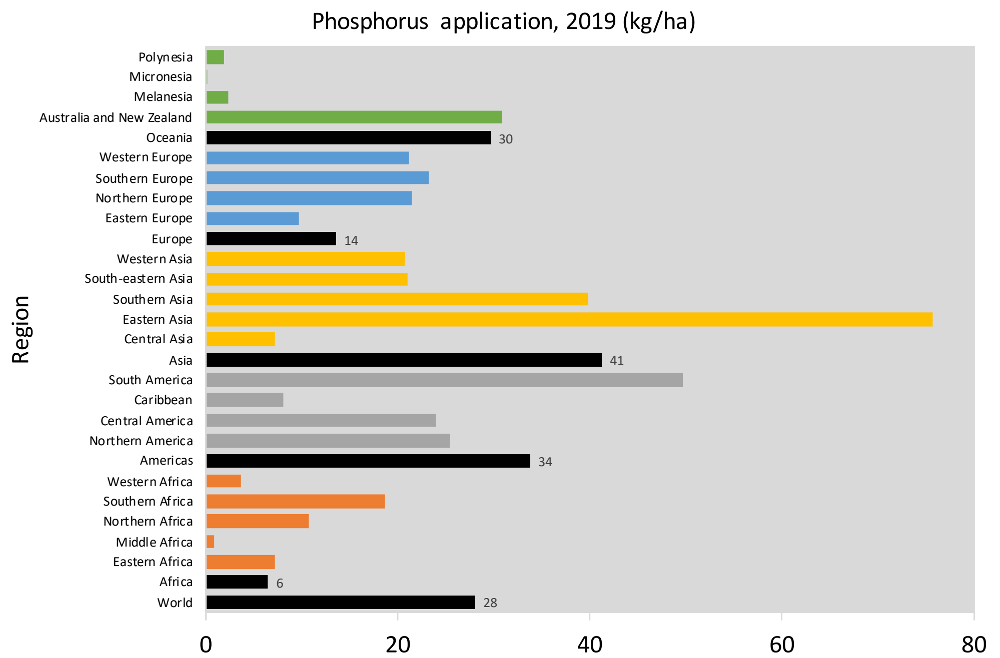
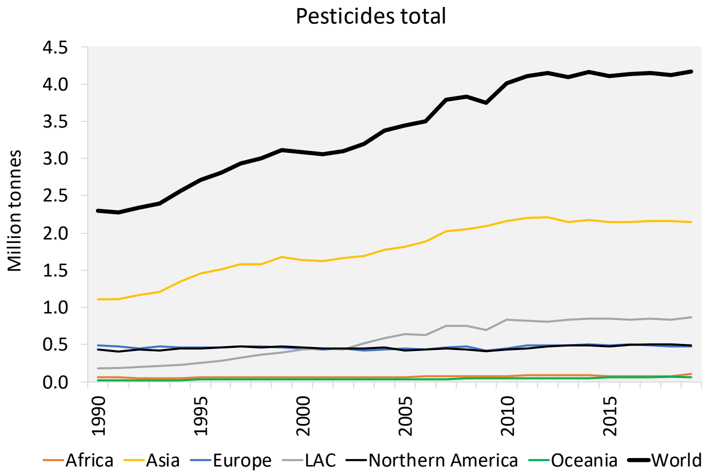
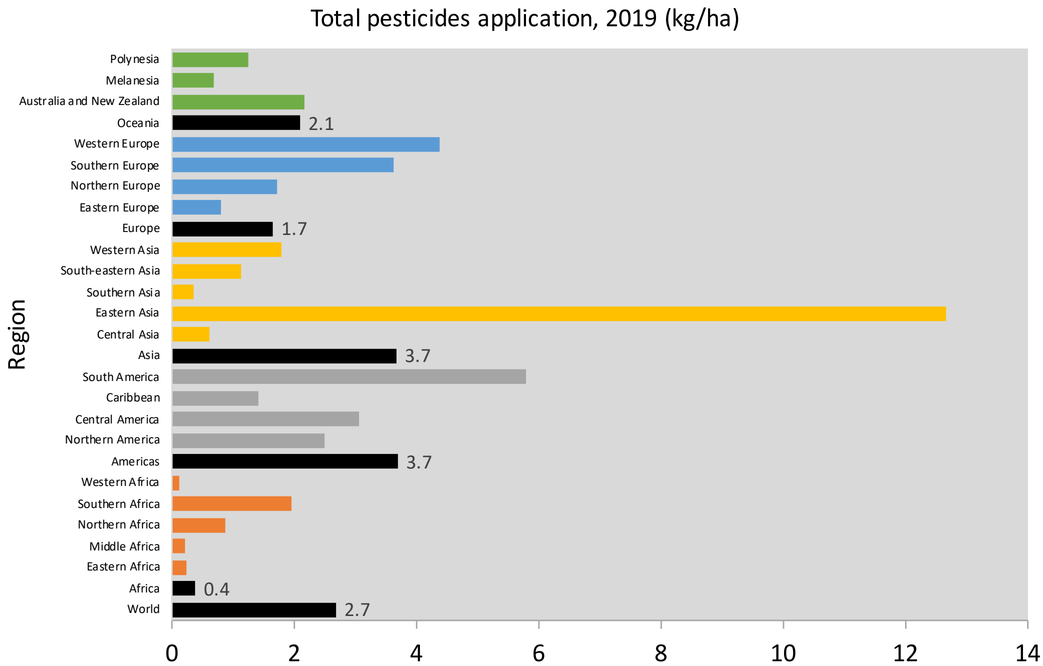


Figure 4.
Current (2019) application rates of nitrogen (N) and phosphorus (P) fertilizer in different regions of the world. Source: FAOSTAT

Pesticide accumulation in wetlands is of growing global concern as pesticide residues can pollute the aquatic environment through direct run-off and leaching and are often toxic to fish and other aquatic species (FAO/IWMI, 2018). Furthermore, pesticides contaminate food sources and can be toxic to people, presenting a significant threat to human health (FAO/IWMI, 2018). Total pesticide use increased in the period 1990-2012 from 2.3 to about 4.1 million tonnes (Figure 5). Since then, pesticide use stabilized. In most regions, half or more of total pesticide use consists of herbicides. Application rates of pesticides are highest (> 12 kg/ha per year) in eastern Asia and also high (4-5 kg/ha) in western Europe and South America.

Figure 5.
Global trend in pesticide use (top) and current application rates in different regions of the world (bottom). Source: FAOSTAT





Water Use, Drainage and Flow Diversion

Agriculture is responsible for around 70% of global freshwater withdrawals, and despite increasing competition in demand for water, agriculture withdrawals continue to increase (FAO, 2020). Agricultural water use in different regions ranges from 28 to 76 % of total water withdrawals depending on the level of economic development (Figure 6). In large areas of Asia, northern Africa, Australia, and the Americas, agriculture intensification disproportionality drives high water stress affecting people and wetlands (FAO, 2020).

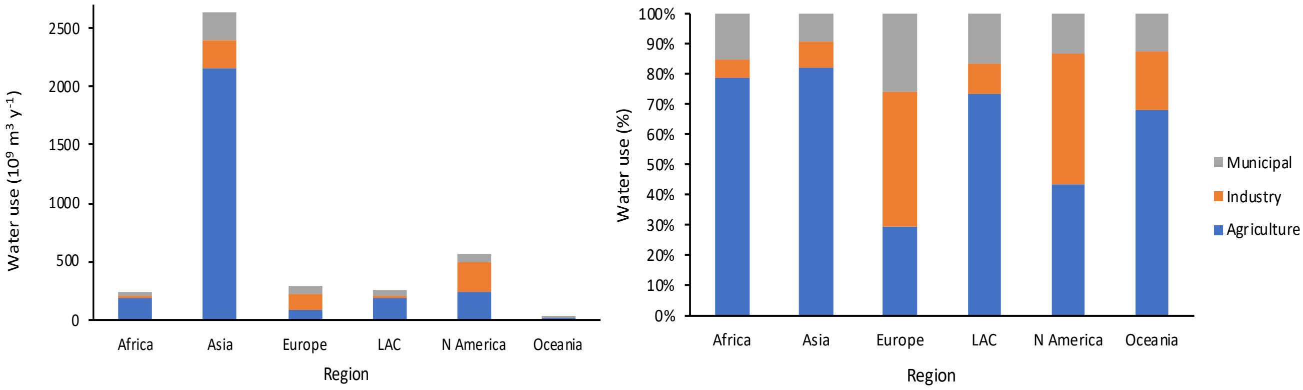


Figure 6.
Agricultural, industrial and municipal water use by world region for 2013-2018. Source: AQUASTAT

Land drainage and river flow diversion for agriculture also modify natural water flow paths with often negative impacts on wetland hydrology and functioning. The total area of drained agricultural land in the world is over 200 million ha (Schultz *et al.* 2005), and in many regions this supports productive farmland, including in deltas of major rivers such as the Mekong and Ganges. About 34% of farmland in Northwestern Europe and 17-30% in the USA is drained to remove excess water and prevent water logging (Gramlich *et al.* 2018).

Erosion and soil degradation

Sediment is supplied to wetlands from wind or water erosion through natural sediment transport processes, as well as from human-induced changes in land or water management, including agriculture. Land conversion and farm practices (e.g., tilling and harvesting) can lead to a significant increase in erosion and soil degradation. In arable and intensively grazed lands rates of soil erosion are 100 to 1,000 higher than natural erosion rates, and far higher than rates of soil formation (Montgomery, 2007; UNCCD, 2017). With high inputs and deposition of sediment to wetlands, nutrients and other chemical compounds are also transported, which can affect the ecological functioning of streams and rivers, floodplains, lakes and forested wetlands. Nutrient losses from soil degradation also lead to increased rates of fertilizer application at high economic and environmental costs (UNCCD, 2017). Soil erosion by water induces annual fluxes of 23-42 Mt of nitrogen and 14.6-26.4 Mt of phosphorus from agricultural land, much of which contaminates freshwater ecosystems (FAO/ITPS 2015).

Extraction of biota

Another major risk to wetlands is from over-harvesting or exploitation of biota (Millennium Ecosystem Assessment 2005).The harvesting of vegetation and animals is a direct outcome of agriculture in wetland ecosystems. Extraction may occur as vegetation clearance, when wetlands are drained for pasture or other land uses, leading to loss of biodiversity. In wetland-based farming systems, extraction of biota is ongoing, as harvest of vegetation, fish or other biota from wetlands. This often provides fodder for livestock, but also for a range of other purposes including medicine, construction, handicrafts, furniture, and fuel.

The Picardy Maritime Plain in France is a wetland shaped by livestock farming. @Nicolas-Bryant/SMBS-GLP

How different agricultural systems interact with inland and coastal wetlands

The impacts of agriculture is context specific and dependent on: a) the type of agricultural system and practices; b) the location of agriculture within a catchment (e.g., in upland areas, floodplains or coastal zone); and c) the types of wetlands involved.

Understanding the impacts of different agricultural practices on wetlands is helped by considering their influence on the four primary drivers of wetland ecosystems: (1) physical regime drivers; (2) extraction drivers; (3) introduction drivers, and (4) structural change drivers (Ramsar Convention on Wetlands, 2018), as shown in Table 3.

Table 3. Interactions between intensive and extensive agriculture systems with inland and coastal wetland types

	Agricultural Systems	a) Rainfed extensive	b) Rainfed intensive	c) Irrigated intensive	d) Horticulture: open	d) Horticulture: glass	e) Livestock extensive	f) Livestock intensive: pasture	f) Livestock intensive: landless	g) Aquaculture extensive: ponds	g) Aquaculture extensive: coastal shell-fish/ seaweed	h) Aquaculture intensive: ponds	h) Aquaculture intensive: cages
Inland	Rivers, streams, floodplains	■	■	■	■	■	■	■	■	■		■	■
	Lakes	■	■	■	■	■	■	■	■			■	■
	Forest wetland	■	■	■	■	■	■	■	■			■	
	Peatland	■	■	■	■	■	■	■	■			■	
	Marshes (on mineral soils)	■	■	■	■	■	■	■	■			■	
Coastal	Estuaries, tidal flats, saltmarshes lagoons		■	■	■	■		■	■		■	■	■
	Mangroves		■	■	■	■		■	■			■	
	Reef systems (incl. coral; shellfish and temperate)		■	■	■	■		■	■			■	■
	Shallow marine waters, seagrass beds, kelp forests		■	■	■	■		■	■		■	■	■
Physical regime	Water quantity/ frequency		■	■	■	■		■		■		■	
	Sediment	■	■	■	■		■	■		■	■	■	■
	Salinity			■	■								
Extraction	Water			■	■	■	■	■	■	■		■	
	Soil & peat	■			■	■				■		■	
	Biota	■	■				■			■	■	■	■
Introduction	Nutrients		■	■	■	■		■	■	■		■	
	Chemicals		■	■	■	■		■	■			■	
	Invasive species		■	■	■	■				■		■	■
Structural change	Solid waste				■						■		■
	Drainage		■	■	■	■		■					
	Conversion		■	■	■	■		■		■		■	
	Burning	■					■						

Sustainable agriculture in the context of the wise use of wetlands

To be sustainable, agriculture must nurture healthy ecosystems and support the sustainable management of land, water and natural resources, while ensuring world food security. As defined by FAO (1988):

"Sustainable agriculture conserves land, water, and plant and animal genetic resources, and is environmentally non-degrading, technically appropriate, economically viable and socially acceptable".

This aligns with the Convention on Wetland's definition of *wise use* and *ecological character* (Resolution IX.1 Annex A):

"Wise use *of wetlands is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development,* and

"Ecological character *is the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time".*

Put simply, to be environmentally sustainable agricultural practices within wetlands, or within the catchments of wetlands, should not adversely affect the ecological character of inland, coastal or human-made wetlands.

Five global challenges for wetlands and agriculture

Food demand is increasing, particularly in developing economies

Global food demand is expected to increase, as the global population of 7.7 billion people in 2019 is projected to grow to 9.7 billion by 2050 (UN, 2019). The growth pattern of developing economies, and changing diets, have broad implications for food demand and in turn agriculture production (GRFC, 2019; FAO, 2020). Despite increased production, food crises including acute hunger continue to affect people in many regions (GRFC, 2019). While wetlands are a rich source of food supply for people in developing economies, unplanned development is impacting wetlands in many regions, as earlier occurred following land use change in developed countries. Drainage and reclamation for agriculture development is taking place without realising the far-reaching consequences caused by changes in the ecological characteristics of wetlands, such acute water shortages and ground water pollution (FAO 2011).

Wetland extent and biodiversity continues to decline

Wetlands are one of the world's ecosystems most in decline. The extent of loss of wetlands and the decline of biodiversity is documented in the *Global Wetland Outlook* with much of this due to the impacts of the expansion and intensification of agriculture globally (Ramsar Convention on Wetlands 2018). Since 1900 a loss of 64-71% of the wetland area has occurred (Davidson, 2014), and around 35% since 1970 (Darrah *et al*. 2019).

Climate change

Agriculture contributes to climate change through land use change (UNCCD, 2017; IPBES, 2019) and energy use. Together, agriculture, forestry and other land uses cause between 20 and 25% of global human greenhouse gas (GHG) emissions (IPCC, 2014; 2019), with the conversion and drainage of wetlands for agriculture directly contributing to increased GHG emissions (Moomaw *et al*. 2018). Globally, some 50 million hectares of peatlands have been drained for agriculture and forestry since 1850 that contribute approximately 4% (2 Gt CO2 -eq/year) of anthropogenic greenhouse gas emissions (Leifeld *et al*. 2019)

Water scarcity

Water scarcity is a global concern for wetlands and people (FAO 2020) that is felt locally, but needs to be dealt with at catchment, national as well as international scales. In many regions of the world, river basins, which are critical to maintain groundwater levels and the overall water cycle, are under water stress due to agricultural withdrawals. As noted in the 2020 assessment on food and agriculture "*almost one-sixth of the world's population live in areas with very high severe drought frequency or very high water stress. Water requirements will only increase owing to population and economic growth, dietary changes and climate change"* (FAO, 2020). This illustrates the tension between providing water to support agriculture, while maintaining environmental flows to wetlands. Wetlands are still often not considered as part of the overall water resources network, with a consequent lack of awareness that loss of wetland connectivity can contribute to water scarcity, as well as to floods.

Water pollution and soil erosion

Water pollution, including excessive amounts of nutrients and pesticides in water and wetland soils, degrades the ecological character of wetlands. The synthesis report on food and water pollution (FAO/IWMI, 2018) was unequivocal, stating "*population growth, changes in calorie intake and diets have increased the demand for a wider variety of foods, including more meat and dairy products, and led to an increased water footprint in terms of water quality. Where the resulting agricultural intensification is not well managed, its benefits for society are often accompanied by significant environmental and health costs, in particular through water pollution*". Further, the loss of organic soils and associated nutrients due to land erosion is a significant concern for agricultural production, reducing crop yields and increasing fertilizer and water use. The annual economic cost of global soil erosion has been estimated to be USD 33-60 billion for nitrogen fertilizer application and USD 77-140 billion for phosphorus (FAO/ITPS, 2015).

Actions - transforming agriculture to sustain people and conserve wetlands

Transformation of the global agriculture system is needed to reverse the trends of environmental degradation, ensure the wise use of wetlands, and respond to climate change. This *need* for global change has been recognised for some time (FAO 2011, 2018a; CGIAR 2021).

Targets for transformation have been formulated in the Sustainable Development Goals (e.g., SDGs 2, 6, 12, 13, 15), the Aichi Biodiversity Targets (e.g., Targets 3, 4, 7, 8, 14, 15) and at various multilateral fora (CBD, 2014; UNCCD, 2017; IPBES, 2019). The Glasgow Climate Pact adopted at UNFCCC COP 26 emphasizes the importance of protecting, conserving and restoring nature and ecosystems to achieve the Paris Agreement temperature goal. Collectively, the global consensus is to move towards more efficient production and more responsible and sustainable land practices, including through better policies, institutional change, and support for the adoption of sustainable farming practices. This includes support for small-scale agricultural producers, including traditional farmers, to become more productive (through integrated agriculture and/or sustainable intensification), while preventing any further loss or degradation of wetlands.

Relevant resolutions adopted by Contracting Parties to the Convention on Wetlands

Resolution XIII.19 on Sustainable agriculture in wetlands (2018) encouraged Contracting Parties to:

- develop sustainable agricultural practices that promote the conservation of wetlands by discouraging wetland drainage and improving management of water resources for wetlands,
- support traditional and innovative uses of wetlands, while maintaining their ecological character, and
- review and adapt programmes, policies and incentive schemes that support agriculture to prevent the degradation of wetlands.

Resolution XI.15 on Agriculture-wetland interactions: rice paddy and pest control (2012) encouraged Parties to:

- address issues relating to pesticides and biodiversity conservation and the wise use of rice paddy wetlands.

Resolution X.31 on Enhancing biodiversity in rice paddies as wetland systems (2008) encouraged Parties to:

- promote the identification, recognition and protection of sustainable rice paddy farming practices that support wetland conservation objectives and provide ecosystem services.

Resolution IX.4 on The Ramsar Convention and conservation, production and sustainable use of fisheries resources (2005):

- noted the growth in aquaculture, its potential benefits, and the need for careful planning and management to avoid negative impacts on wetlands, and
- urged Parties to address issues pertaining to the sustainable use of fisheries resources in relation to the conservation and wise use of Ramsar sites and other wetlands.

Resolution VIII.34 on Agriculture, wetlands and water resource management (2002):

- noted concerted efforts are required to achieve a balance between agriculture and the conservation and sustainable use of wetlands, and to prevent or minimize the adverse effects from agricultural practices on the health of wetland ecosystems, and
- called on Parties to ensure management plans for Ramsar sites and other wetlands acknowledge the need to implement agricultural practices compatible with wetland conservation and sustainable use goals, and to identify subsidies or incentives that may be having negative impacts on water resources.

Actions at multiple scales will require the agricultural sector, policy-makers, financial institutions and wetland managers to work together. For example, responses should include:

- Applying a combination of financial measures to support the livelihoods and improve the standard of living of wetland users, to lift them out of poverty and reduce the need to further degrade the wetland resources they depend on (Falkenmark *et al.* 2007). Such measures could ensure enabling better access to markets for their produce, alongside incentives to maintain key elements of wetlands;
- Improving technology and sharing knowledge to enhance the adoption of integrated agricultural practices, including agroecology/regenerative agriculture (FAO 2018b, Lal 2020), permaculture, paludiculture and other low input farming systems (Wu & Ma 2015);
- Enhancing the role of wetlands (whether natural or constructed) as nature-based solutions to reduce pollutant transfer in the environment (UN Water 2018, Miralles-Wilhelm 2021), alongside stronger measures to reduce pollution at source;
- Working with the agricultural sector to maintain or restore environmental flows to wetlands (Barchiesi *et al.* 2018) and to embed wetland hydrological requirements in water resources planning;
- Restoration of wetlands for climate change mitigation. Mitigation actions with immediate impacts include the conservation of high-carbon ecosystems such as peatlands, and mangroves (IPCC 2019);
- Wetland-specific climate adaptation (Moomaw *et al.* 2018). For example, the allocation of water away from irrigation or other water uses to environmental flows to sustain or restore wetlands, including recharging important groundwater sources when conditions allow.

Five overarching principles have previously been defined to achieve sustainability in agriculture, and to meet the SDGs (FAO 2014, 2018a). The high-level principles were: (1) *Improving efficiency in the use of resources is crucial to sustainable agriculture*, (2) *Sustainability requires direct action to conserve, protect and enhance natural resources*, (3) *Agriculture that fails to protect and improve rural livelihoods, equity and social well-being is unsustainable*, (4) *Enhanced resilience of people, communities and ecosystems is key to sustainable agriculture*, and (5) *Sustainable food and agriculture requires responsible and effective governance mechanisms*.

Adapting and applying these principles for wetlands is considered a key strategy to transform agriculture, globally and locally, to ensure the wise use of wetlands under the Convention on Wetlands (van Dam *et al.* 2021). The framework presented in **Figure 7** illustrates the specific actions needed for wetlands. Its purpose is to foster dialogue between policy-makers, wetland managers, local farmers and industry groups.

It is equally important to illustrate how transitioning to sustainable agriculture is possible. This Briefing Note contains **six case studies** that demonstrate how action can be taken to increase collaboration and dialogue between wetland and agriculture sectors, reduce the pressures on wetlands from agriculture, including at Wetlands of International Importance, and use market or social mechanisms to promote sustainable agriculture and wetland wise use.

Figure 7. Actions to transform agriculture to sustain people and ensure the wise use of wetlands. Adapted from FAO (2014), FAO (2018), van Dam et al. (2021)

1. Increase efficiency in the use of resources

Ensure efficient use of water resources and protect water sources for wetlands

Limit use of fertilizers and pesticides near wetlands

Transition to integrated crop-livestock-fish agricultural practices, or other low input or natural farming systems

2. Protect and enhance natural resources

Stop conversion of wetlands

Restore degraded wetlands

Improve agricultural practices to reduce pressures on the ecological character of wetlands

3. Improve livelihoods, and foster inclusive economic growth

Apply financial mechanisms to promote sustainable practices and wetland wise use

Recognise the role of local farmers in maintaining cultural and regulating services

Promote integrated farming (diversification) for economic, climate and ecosystem resilience

4. Enhance the resilience of people, communities and ecosystems

Manage wetlands to maintain their natural capital and services to agriculture and people

Support traditional agriculture to retain links between cultural identity, wetlands and human wellbeing

Identify future climate scenarios and adapt agricultural practices for wetlands

5. Adapt governance to new challenges

Build cross-sectoral collaboration

Develop policy responses that set catchment limits on water use and pollutants

Improve institutional and finance frameworks to avoid, mitigate, and offset the adverse effects of agriculture on wetlands and promote sustainable food production

Outcomes for wetland wise use

Positive collaboration and dialogue between wetland and agriculture sectors

Reduced pressures on wetlands from agriculture, including at 'Wetlands of International Importance

Increased resilience of wetlands and people under a changing climate and greater food demand

Wise use of wetlands as nature-based solutions to support sustainable agriculture

Case study 1: Addressing agricultural pressures on wetlands: Balancing fish rearing and biodiversity conservation in the Třeboň fishponds, Czech Republic

In the Czech Republic, human-made shallow wetlands are important for aquaculture as well as biodiversity. These wetlands date back to the 10th and 11th centuries and were historically constructed around monasteries. Over many centuries, about 180,000 ha of fishponds were made, although many were subsequently drained and used for other agricultural uses (crops and livestock) or settlements. Today, only 52,000 ha of fish ponds remain.

The principal fish species reared in Czech fishponds is the Common Carp (*Cyprinus carpio*), but, several other species have been added to fish stocks through history. Around the 16th century fishponds yielded ~40 kg/ha of fish, but since then have increased steadily, reaching the current day yields of 450–500 kg/ha due to supplementary feeding and input of nutrients. However, such intensive practices have direct impacts on wetland ecosystems leading to eutrophication, excessive algal growth, deterioration of water quality and loss of biodiversity.

To illustrate the benefits of low-impact aquaculture, fish stocks in the Rod fishpond Nature Reserve were experimentally reduced between 2014-2019. The Carp harvest was 294 kg/ha in 2017 compared to 423-607 kg/ha in 2011-2013. The lower fish-stock density triggered positive renewal of zooplankton and submerged aquatic plants that supported much higher numbers of waterbirds. Addressing the direct impacts of intensive aquaculture had clear benefits for biodiversity.

Like most fishponds in the Třeboň Basin Biosphere Reserve the Rod fishpond is owned by the Třeboň Fishery. As the fishery company adopts low-impact fish rearing the Czech Ministry of Environment, in return, compensates for the loss of fish yields, providing an incentive for applying more sustainable practices.

Fishpond after reduction of fish stock that promoted recovery of wetland biodiversity. © Martina Eiseltová

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Case study 2: Transitioning to sustainability at catchment scales – A partnership between agriculture and conservation sectors at Waituna Lagoon, New Zealand

Waituna Lagoon catchment in New Zealand is a good example of how the environmental and agriculture sectors can partner to enable farming and wetlands to co-exist. The New Zealand Department of Conservation (DOC) and Fonterra, New Zealand's largest dairy cooperative, entered into a ten-year Living Water Partnership in 2013, to address the impacts of agriculture intensification on biodiversity.

At the time the Living Water Partnership was formalised, farmers were intensifying practices in response to economic opportunities and environmental groups were raising alarms about the role of agriculture in the decline of water quality. Seven years into the partnership, the value of what was an unlikely alliance has helped reconcile formerly polarised views and move towards more sustainable solutions in the Waituna Lagoon catchment, part of the Awarua Wetland Ramsar site.

This highly valued wetland, significant to the local indigenous people of Ngāi Tahu, showed signs of stress with the decline of a keystone aquatic plant *Ruppia,* due to agriculture intensification upstream. Despite recommendations for changes in agricultural practices (Environment Southland, 2013; Schallenberg *et al.* 2017), which required a 50% reduction in both nitrogen and phosphorus, an economic analysis indicated that 26% of farms might be unviable and up to 140 jobs lost (Taylor Baines and Associates, 2015), if the nutrient targets were to be met.

In 2018, the opposing groups were united in their aspirations to preserve the health of the lagoon. A renewed Strategy and Action Plan for the catchment combined engineering solutions with a transition in farming practices. This brought the agriculture sector, via the Living Water Partnership, firmly to the table in terms of decision making and delivery – through individual farm mitigations and collective approaches, such as land retirement and constructed wetlands (Bright *et al.* 2020). With a 2.6 million New Zealand dollars commitment from the DOC-Fonterra Living Water Partnership, 13 million New Zealand dollars were raised to purchase low-lying farming land adjacent to Waituna lagoon and support catchment-wide nutrient reduction.

The execution of this plan, while ambitious, is much more achievable in a united social environment than one that is polarised and focused on problems, rather than solutions.

Farmland surrounding Waituna Lagoon in Southland, New Zealand. © Living Water Partnership

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Living Water Partnership: https://www.livingwater.net.nz/

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Case study 3: Use market or social mechanisms to promote sustainable agriculture and wetland wise use – Stork-friendly rice farming at Toyooka City, Japan

Toyooka City was the last habitat where wild Oriental White Storks (*Ciconia boyciana*) were reported in Japan (1971). The extinction of this bird species was attributed to environmental degradation and the use of agrochemicals for rice production, which destroyed its natural food resources - fish, frogs, and other aquatic animals.

In an initiative to re-introduce the stork and other migratory birds to the cities, the municipal government, together with farmers, NGOs, and researchers, embarked on a breeding programme for the Oriental White Storks and restoring wetlands in the river basin.

To be a success agricultural practices had to change drastically. Concerted action included a new "Stork-Friendly Farming Method" that, avoids the use of pesticides or chemical fertilisers, delays the draining of water from rice paddies to allow for tadpoles to transform into frogs and larvae into dragonflies, and creates wintering habitats for migratory birds such as Tundra Swan (*Cygnus columbianus*). Building biodiversity in rice paddies, in return, enhances soil cultivation and helps control agricultural pests.

Today, the Stork-Friendly Farming Method has expanded to over 400 ha mainly in the Lower Maruyama River --- up from 0.7ha in 2003. And since reintroducing the storks back into the wild in 2005, their population has grown to more than 200.

Since nature-based solutions have been adopted, the gross incomes of farmers have increased because the insecticide-free rice fetches a higher price (~150%), despite the reduced yields (80% of standard cultivation). Backed by the story of reintroducing the Oriental White Storks, markets for the Stork-friendly branded rice have expanded in Japan and overseas to the United States of America, Hong Kong, Australia, the United Arab Emirates and Taiwan. The product is endorsed by food businesses, chefs and consumers around the world. While stork-friendly farming is labour intensive, the goal of balancing "delicious rice production with conserving biological diversity" is being achieved.

An Oriental White Stork flying over the rice paddy.
© Toyooka City

Further Information:

Toyooka City stork farming: https://toyooka-city.jp/stork-farming

Case study 4: Increase resilience of wetlands under a changing climate and greater food demand – applying tools to improve sustainability, Pantanal, Brazil

The flooded open grasslands and savanna of the Pantanal have supported beef cattle raising for over 200 years. Historically, livestock grazing had relatively low stocking rates but an increase in the use of intensive less eco-friendly farming practices now threatens the delicate balance of one of the largest, and most diverse wetlands, in the world.

Today, private ranches occupy ~95% of the Pantanal and in many areas are farming unsustainably. In an attempt to restore and wisely manage wetlands, the "Sustainable Pantaneira Ranch" (SPR) programme has been promoted by Embrapa Pantanal in partnership with Embrapa Informática. The SPR tool evaluates ranch sustainability, helping farmers identify practices that have low environment impact (green technologies), maintain the biodiversity of wetlands, alleviate climate change effects and support ecosystem services.

Covering an array of sustainable practices, the tool addresses issues like social welfare, economic viability, livestock welfare and management, pasture productivity and conservation, biodiversity conservation, water resources availability and conservation. When applied in the Paiaguás sub-region, use of SPR led to a change in farming systems to improve water conservation strategies, reduce threats to native pastures and revise financial planning to allow for transition to low-impact practices.

Open grassland that supports extensive livestock agriculture, Pantanal, Brazil. © Sandra Santos

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Case study 5: Collaboration and dialogue between wetland and agriculture sectors - reducing insecticide use without impacting profitability, Marais Audomarois, France

The Audomarois wetland in the north of France is a 3,726 ha peatland, designated under the Convention on Wetlands in 2008 and recognised as a Biosphere Reserve in 2013. The marsh landscape developed from over 13 centuries of livestock farming and market gardening. Renowned for its summer cauliflower, the farmers of the Marais Audomarois are becoming fewer and the wetlands are losing their ecological richness due to intensive farming practices.

In response, the CAPSO (Communauté d'Agglomération du Pays de Saint-Omer) has piloted the Programme for the Maintenance of Agriculture in Wetlands (PMAZH), following agro-ecological practices, with financial support from the Artois-Picardie Water Agency. The programme helps market gardeners reduce pesticide use, without effecting profitability, by introducing biological control methods (use of natural enemies -"crop auxiliaries"), supplemented with annual flowers to attract insects and nest boxes for birds that consume caterpillars.

The results have been rewarding. Today the wetland-farming landscape is studded with rows of flowering plants attracting syrphid flies, lacewings (chrysopa), ladybirds and other insects – that enable cauliflower production with less use of agrochemicals and which find a balance between wetland biodiversity and agriculture. Market gardeners are now experimenting on using perennial species, in a wider area to increase the nectar producing resources favourable to crop auxiliaries.

The market demand for perfect cauliflowers forces the gardeners to use insecticides. This programme is a pathway to change, both in mind sets and practices, offering innovation and sustainable solutions for people and wetlands.

Monthly meeting of market gardeners and technical experts to assess the efficiency of biological regulation in fields. ©Gautier Vancleenputte, Hauts-de-France Chamber of Agriculture

Further Information:

Project supported by CAPSO in partnership with the Hauts-de-France Chamber of Agriculture, the Hauts-de-France Regional Federation for Defence against Pests and the Bailleul National Botanic Conservatory.

Case study 6: Addressing direct drivers of wetland degradation - restoring the Winton wetlands, Australia

The Winton Wetlands, in the south-eastern part of the Murray-Darling Basin, Australia, is a real-time example of a wetland restoration programme involving ecological and social renewal efforts - where the cycle of degradation caused by agricultural development is being reversed.

A series of historical events characterise the gradual deterioration of the wetland's values to people: first Aboriginal inhabitants losing their land to European settlers for farming, followed by new settlers losing their land in 1970, because of the formation of Lake Mokoan, a reservoir supporting irrigated agriculture. The impounded dam resulted in the loss of natural wetlands and killed around 150,000 iconic trees, including many Aboriginal scar trees.

While the irrigation dam was intended to support agriculture, in 2004, a contentious decision was made to remove the dam – due to the occurrence of low water levels, blue-green algal blooms and the need for water savings to support water projects elsewhere. The water from the lake was drained and the infrastructure was decommissioned, and that presented an opportunity to remedy the impacts of previous agricultural development on the Winton wetlands.

A community-based committee, that recognises both Indigenous and non-Indigenous cultural heritage, has prepared a renewal plan for an 8750 ha site, to achieve ecological and social restoration. Social renewal plans (art and recreational events) for repairing the links to wetlands and people are already showing results. Specific management actions have been launched to establish self-sustaining populations of native fish, waterbirds and other fauna, and aquatic plants. These are also improving water quality and reducing the populations of feral animals and weeds. Visitor numbers have increased and there is evidence of ecological repair across the wetland.

Dead trees because of flooding when the wetlands were inundated following construction of a dam to store water for irrigated agriculture. © Max Finlayson

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Annex 1. Key characteristics of agricultural systems

Agricultural system	Water use	Fertilizer use	Nutrient use	Chemical use	Potential erosion	Agri-cultural diversity	Impact on biodiversity	Geographic location	Direct impact on wetlands	Indirect impact on wetlands
A. Cropping/ livestock - extensive	low, mainly for livestock	low-med, also organic	low-med- in good practice	medium	low-med	med-high	low-med	close to high productive and arid areas	low	low-med
B. Cropping/ livestock - intensive	low-med, processing of harvest, livestock	med-high	med-high, depends on practice	high	high	low	high	mainly temperate, lowlands	high	med
C. Irrigated cropland	high, irrigation and processing of harvest	high	often high	high	high	low	high	arid areas, basins, lowlands	high	high
D. Horticulture	high	high	high	high	low-med	low-med	med	areas with good water access, high productive regions	low-med	high
E. Livestock - extensive	low	low indirect (fodder)	low	low or indirect	low-med	usually high	low	arid areas, mountain regions, only pastures feasible	low-med	low
F. Livestock -intensive	high	high indirect (feed/ fodder)	low-high, depends on practice	high indirect (fodder)	high - low, indoor	low	high	lowlands with good water availability	med-high	high (fodder imports)
G. Aquaculture - extensive	low	low	low-med	low	low	low	low-med	areas with good freshwater access; coastal areas	med-high	med-high (water use)
H. Aquaculture - intensive	low/high (depends on system)	high, also indirect (feed)	low-high, depends on practice/ system	med	low	low	high	areas with good freshwater access and terrain for ponds; coastal areas	low - high (depends on system)	low - high (depends on system)
I. Integrated agriculture	low	low, mainly organic	low-med, depends on practice	low	low	high	low	global	low	low

Sources: FAO (2011a; 2011b); Gaudet et al. (2018) ; IPBES (2018); Wood & van Halsema (2008)

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