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Draft Briefing Note on Wetlands and agriculture: impacts of farming practices and pathways to sustainability

Ramsar Briefing Note No.xx

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

[Sidebar]

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

The Scientific and Technical Review Panel (STRP) of the Ramsar Convention on Wetlands recommended in its 2019-2021 work plan to compile information on positive and negative impacts of agricultural practises on wetlands, and how adverse impacts can be avoided in the future. The Standing Committee identified this as one of the STRP's highest priority tasks.

Relevant Ramsar documents

Ramsar Policy Brief X. *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*
Ramsar Policy Brief 2. *Integrating multiple wetland values into decision making*.
Ramsar factsheet 7 on *Wetlands: Source of sustainable livelihoods*
World Wetlands Day 2014 leaflet on *Wetlands & Agriculture*
Scaling up wetland conservation, wise use and restoration to achieve the Sustainable Development Goals: Wetlands and the SDGs

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Summary
Transformation of agriculture is needed to reverse the trend of wetland loss and degradation, while simultaneously providing food for the increasing human population. 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 promote positive examples of efforts to transition to more sustainable agriculture and the wise use of wetlands. 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 Ramsar site, Colombia. Source: Case study

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 Ramsar sites, are under pressure from agriculture**. The extent of natural wetlands has declined by 35% since 1970, while human-made wetlands, including rice paddy fields and reservoirs, increased by +233%. Various studies indicate that agricultural development is a primary cause of wetland loss. Over the past 20 years the intensification of agriculture has also led to increased extraction and diversion of water for irrigation and an increasing global trend of fertiliser and pesticide application.

- A**gricultural practices within wetlands, or within the catchments of wetlands, should not adversely affect their ecological character**.

- **Knowledge of the interactions between different types of agriculture (intensive, extensive, integrated) and inland, coastal and human-made wetlands is needed** to improve environmental policies and guide on-ground initiatives to promote sustainable agriculture.

- **The growing demand for food, the pollution and/or conversion of wetlands, and increasing water scarcity**, are critical issues that need to be addressed in particular under a changing climate.

- **The transformation to sustainable agriculture is possible** and is demonstrated through case studies which highlight the importance of addressing direct and indirect pressures on wetlands through cross-sector collaboration.

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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 (FAO, 2019).

The interactions between wetlands and agriculture can take many forms. To understand wetland-agriculture interactions, it is important to distinguish between different types of wetland and agriculture systems. Some types of farming systems are inherently more efficient in the way they extract biota and use water and nutrients to produce food than others, which influences their impact on wetlands. To ensure the wise use of wetlands, we need to better communicate both the positive and negative impacts of agriculture on wetlands and identify pathways to transform agriculture to support the goals of the Ramsar Convention and sustainable development.

Livestock and wild herbivores grazing, Pantanal wetland, Brazil. Source: Case study

[Box] **Definitions**
"Agriculture" is the deliberate effort to cultivate crops and/or raise livestock for sustenance or economic gain, and include 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 Ramsar Convention 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".

[Box] **Previous Ramsar Resolutions on wetlands and agriculture**
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):

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

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

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 addressed 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

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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 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 from an increase use of resources, particularly water and agrochemicals. 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 (fertilisers and pesticides) (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
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, all definitions according to the respective data source.
[1]Area total: Total land area per continent.
[2]Agricultural land: the combined area of cropland (1/3) and permanent pasture and meadows, including rangeland, permanently used for livestock grazing (2/3).
[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.

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Wetlands support agriculture and people

Wetland ecosystems as defined by the Ramsar Convention include inland, coastal/marine and human-made wetlands and are estimated to cover an area >1.5 billion hectares (Davidson & Finlayson 2018). They provide many ecosystem services to humanity, inland wetlands have been valued as providing over $USD 25,000 per hectare/year of services in monetary terms (De Groot et al., 2012).

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

Wetlands further support agriculture by regulating the environment, 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 Ramsar sites indicates approximately 49% of sites provide flood control or storage and 21% of sites facilitate the cycling of nutrients (Figure 1).

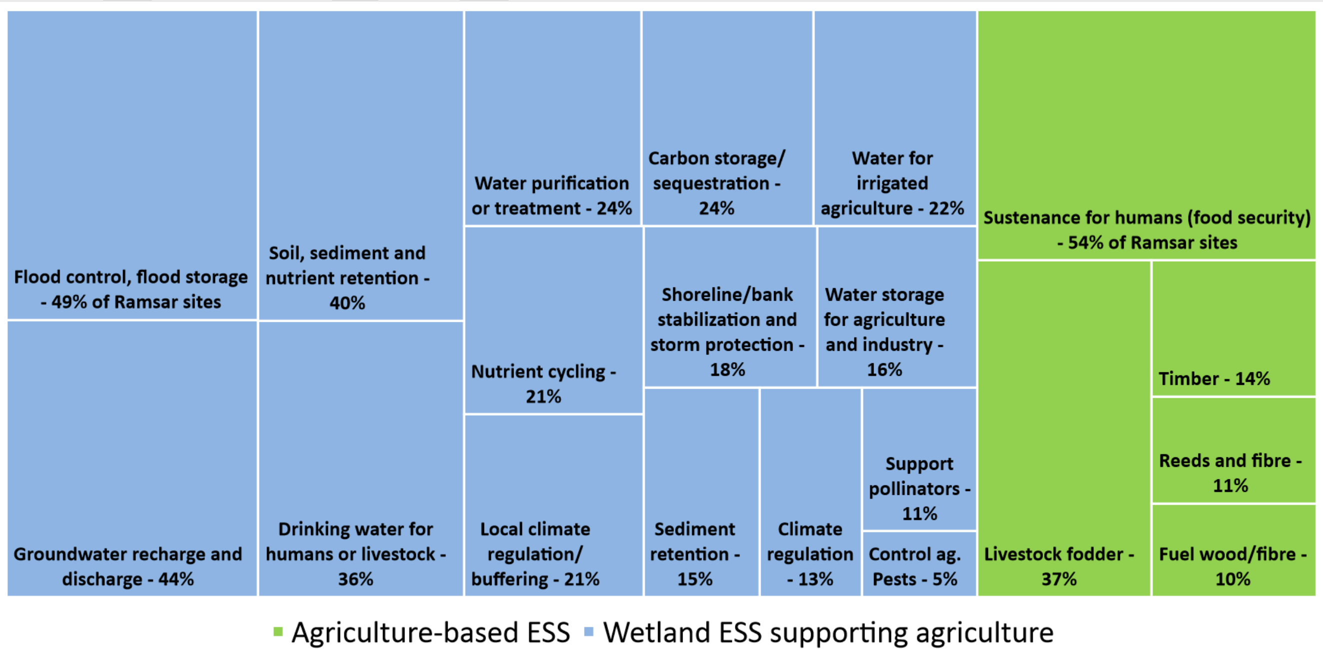

Figure 1. Ecosystem services (ESS) and agriculture at Ramsar Sites*. The percentage (%) of Ramsar sites that i) support agriculture by helping to regulate the environment (wetland ESS supporting agriculture and ii) provide sustenance** or crops from harvest (agriculture-based ESS).

Notes:

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

** the 54% of Ramsar Sites that provide sustenance for humans includes wetlands that provide wild food resources, including capture fisheries.

Agricultural threats to Ramsar Sites

Ramsar Sites are recognised as internationally important wetlands, particularly for the conservation of biodiversity. But many Ramsar Sites are under pressure from agricultural practices. Review of RIS (Ramsar Information Sheet) data on the anthropogenic pressures affecting wetlands indicates that agriculture-related practices (or pressures) are likely to be, or, having a negative effect on >50% of the world's Ramsar sites.

The RIS data indicates agricultural practices occurring near Ramsar Sites are contributing to wetland degradation via several mechanisms (Figure 2). For example, more than 20% of the world's Ramsar Sites affected by dams or drainage, recognising not all water infrastructure is built to support agriculture. More than 20% of Ramsar sites are also affected by livestock farming, agricultural and forestry effluents or land conversion (Figure 2).

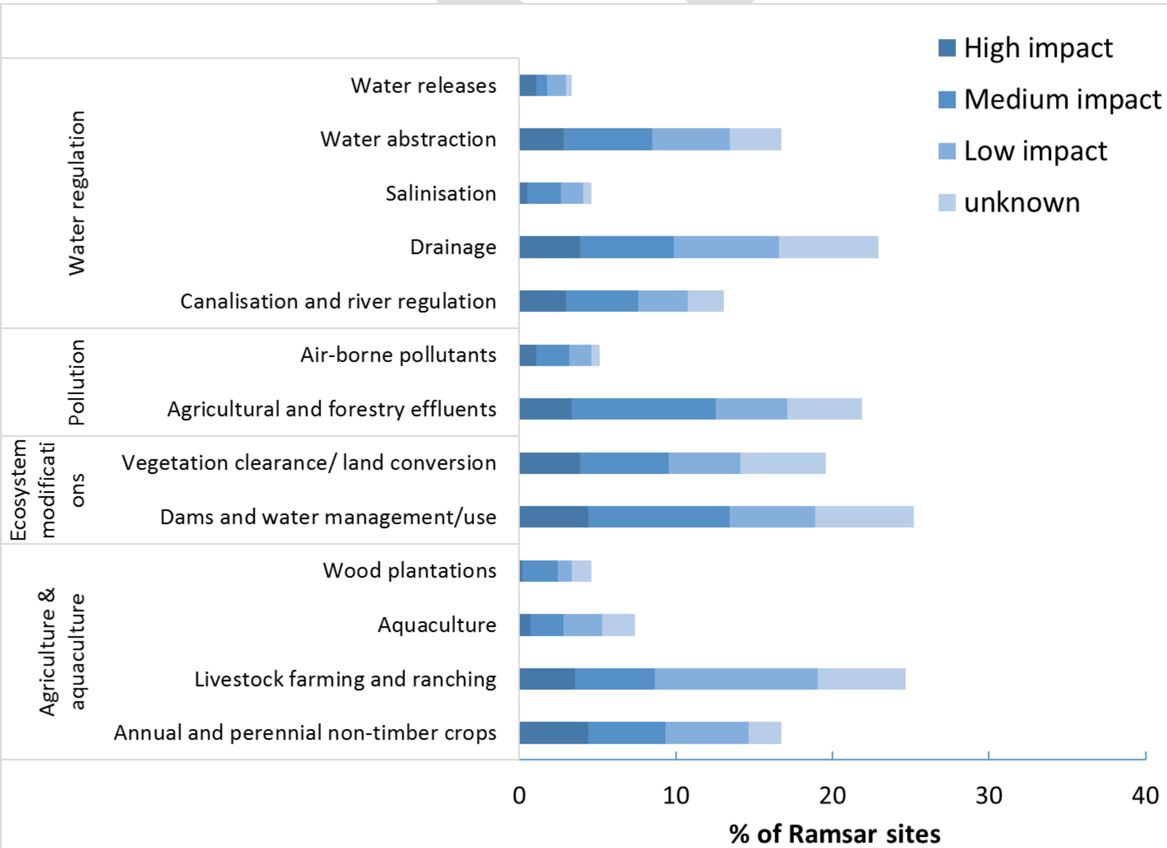

Figure 2. Agricultural threats on Ramsar Sites*. The percentage (%) of Ramsar sites negatively affected from agriculture-based practices (threats).

Notes:

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

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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 a regions' bio-geophysical characteristics, as well as 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 (categories) 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) enables the evaluation of 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 - category**	**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 and goats, all ruminants 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 includes non-fed ponds and enclosure systems (cages or pens) for 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. In many regions intensification of farming has reduced-integration and led to mono-cropping, with the loss of traditional practices.

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

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How agricultural systems interact with wetlands

Agricultural systems interact with wetlands in many ways, indirectly and directly. Indirect drivers operate at catchment and river-basin scales and can have delayed interactions with wetlands through system-wide changes in water, sediment, biota and pollutants, leading to an overall degradation of the landscape. Direct agriculture-wetland interactions are affected by wetland conversion, water use, drainage, nutrients, erosion, soil degradation and extraction of biota at the wetland-scale. In poorly managed agricultural systems, there are many ways in which agriculture can degrade wetlands and 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 for improving agriculture-wetland interactions (Wood & van Halsema, 2008).

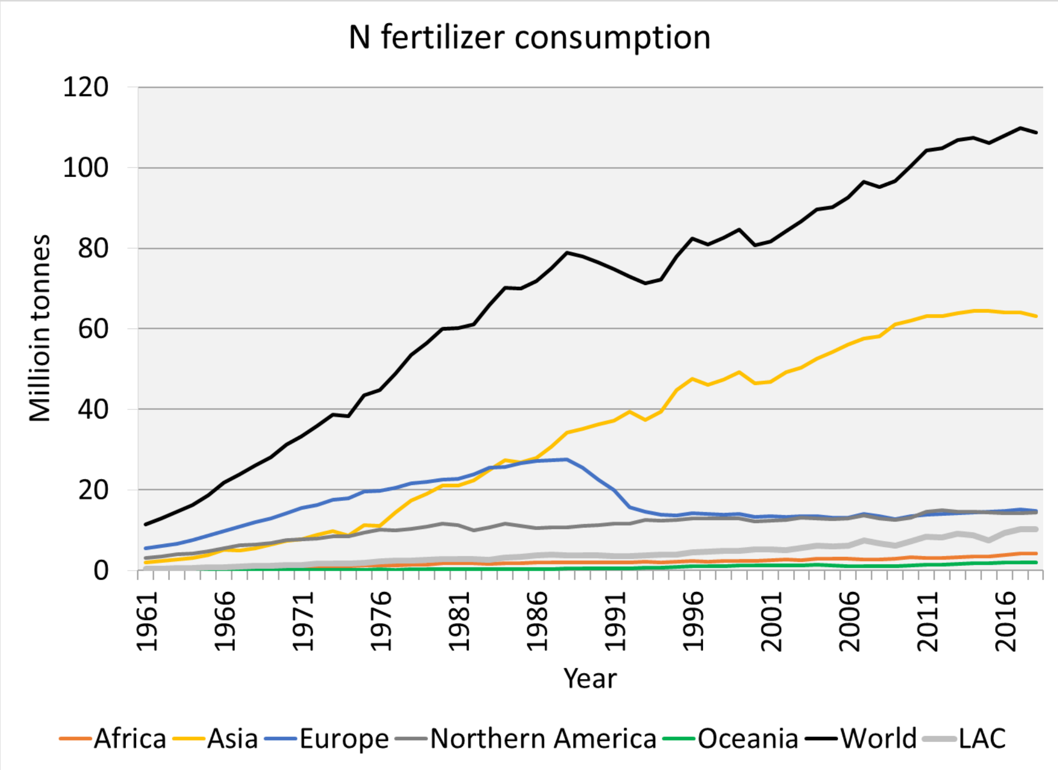
Land conversion

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 between 1.5-1.6 billion hectares (Davidson & Finlayson 2018). Due to land conversion of the extent of natural wetlands declined by -35% between 1970-2015, 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 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 contributes to 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, 2018).

Contaminants – Nutrients, Fertilisers and Pesticides

Water pollution is caused by excessive fertilizer use, application of pesticides, and 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 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).



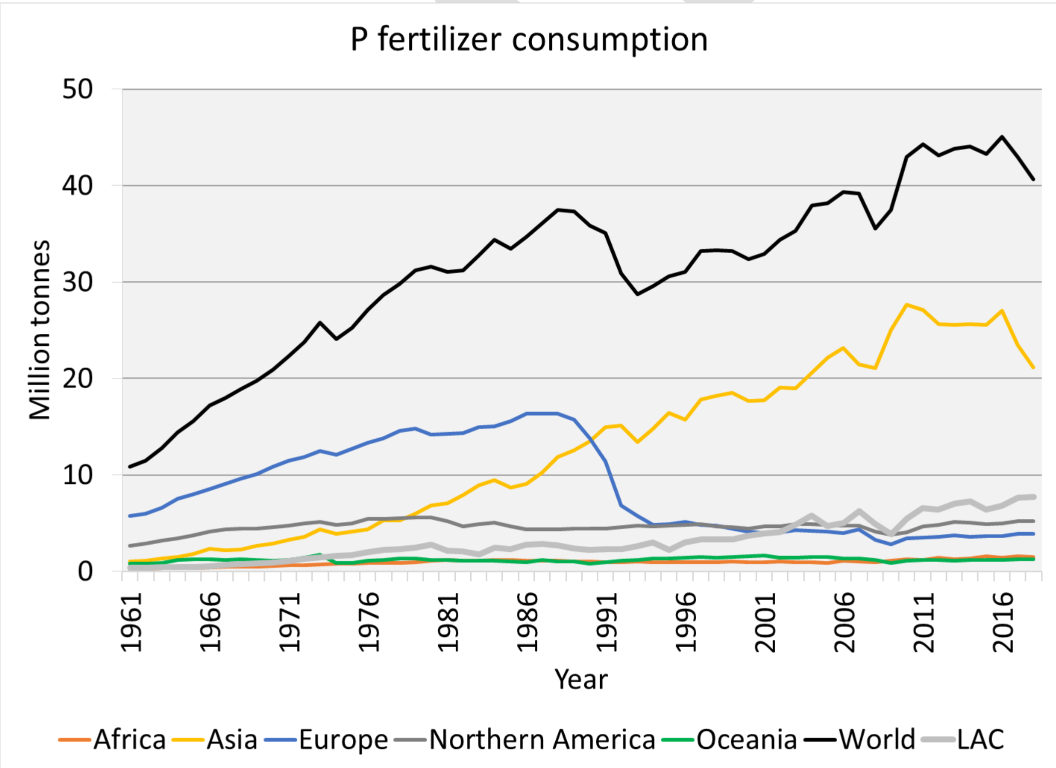


Figure 3. Global trends in nitrogen (N) and phosphorus (P) fertiliser use. Source: FAOSTAT

High use of fertiliser within or near wetlands increases surface water and groundwater inputs of N & P 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 N and 26 kg/ha of P 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).

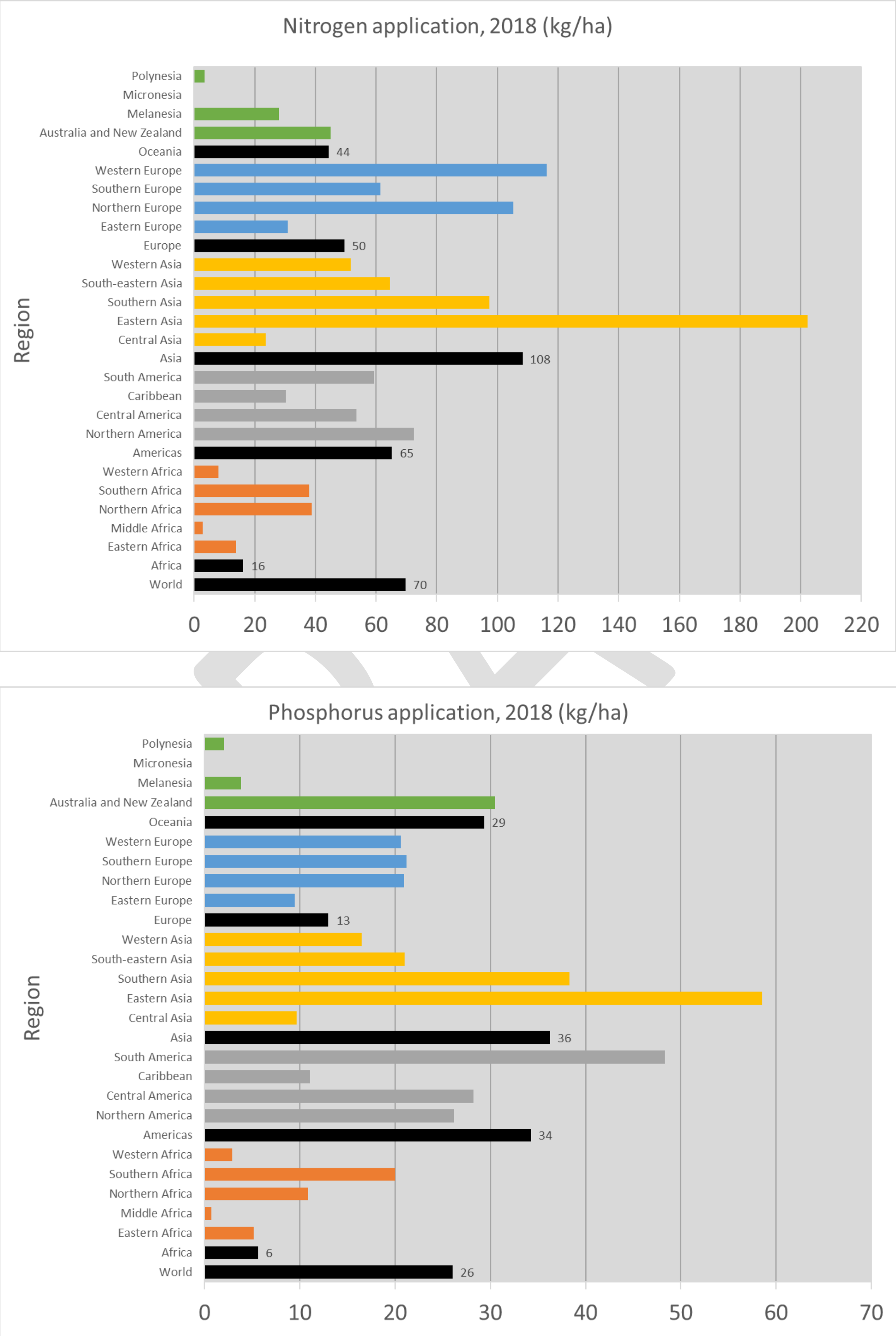
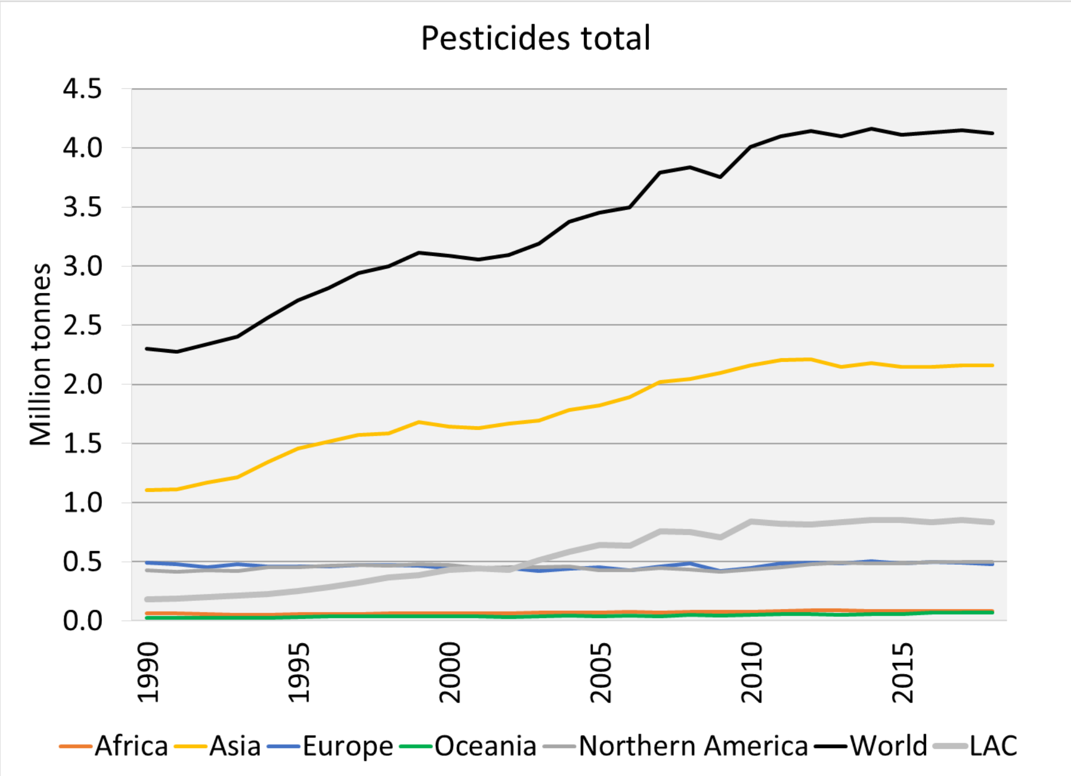


Figure 4. Current (2018) application rates of nitrogen (N) and phosphorus (P) fertiliser in different regions of the world. Source: FAOSTAT

Pesticide accumulation in wetlands is a growing global concern as pesticide residues can pollute the aquatic environment through from direct run-off and leaching and are often toxic to fish and other aquatic species (FAO/IWMI 2018). Furthermore, pesticides can 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 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 (4-5 kg/ha) in western Europe, South America and, with very high rates (> 12 kg/ha per year) in eastern Asia.



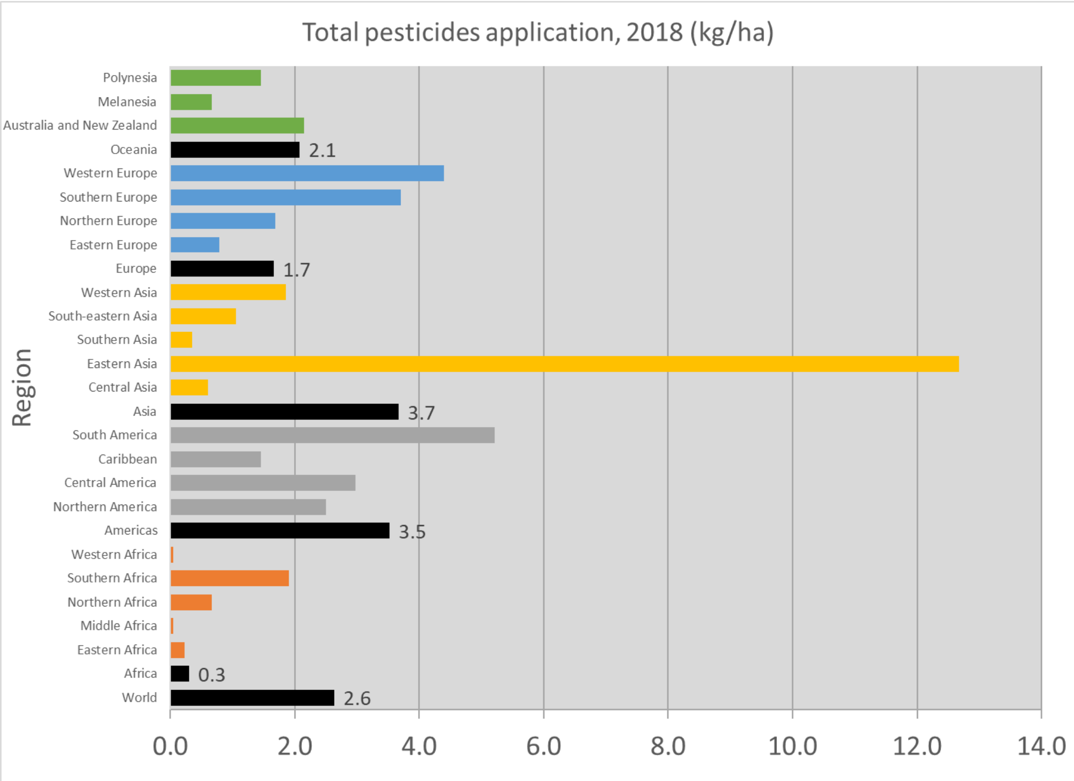


Figure 5. Global trend in pesticide use (top) and current application rates in different regions of the world (bottom). Source: FAOSTAT

Water Use, Drainage and Flow Diversion

Agriculture is responsible for around 70% of global freshwater withdrawals, and despite increasing competition in the 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 (Table 3). However, in large areas of Asia, northern Africa, Australia, and the Americas, agriculture intensification disproportionality drives high water stress affecting people and wetlands (FAO 2020).

Table 3. Agricultural, industrial and municipal water use by world region for 2013-2017 (Source: AQUASTAT).

2013-2017	**Agriculture**		**Industry**		**Municipal**		**Total**
	10^9 m^3 y^{-1}	%	10^9 m^3 y^{-1}	%	10^9 m^3 y^{-1}	%	10^9 m^3 y^{-1}
Africa	103.6	76.2	11.4	8.4	21.1	15.5	136.0
Asia	841.0	72.7	178.2	15.4	137.6	11.9	1156.9
Europe	79.9	28.4	133.2	47.4	68.2	24.2	281.3
LAC	67.5	61.3	16.2	14.7	26.3	23.9	110.0
N America	245.6	43.3	244.6	43.1	77.5	13.7	567.7
Oceania	10.5	63.4	2.7	16.1	3.4	20.5	16.6

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 NW 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, harvesting) can lead to an increase in erosion and soil degradation, and in arable and intensively grazed lands can be >100x higher than natural erosion rates (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.

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

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

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How different agricultural systems interact with different wetland types
The interactions of agricultural systems with wetlands is context specific and dependent on: a) the type of agricultural system and practices; b) the location within a catchment where the agricultural activities take place (e.g. in the upland areas, in the floodplains or in the coastal zone); and c) the types of wetlands involved.

Systematic assessment of interactions of different agricultural practices on wetlands is facilitated by considering how the four primary drivers of wetland ecosystems (1) physical regime drivers; (2) extraction drivers; (3) introduction driver, and (4) structural change drivers (Ramsar Convention, 2018) are each influenced by intensive and extensive agriculture systems, as demonstrated in Table 4.

Table 4. Interactions between intensive and extensive agriculture systems with inland and coastal wetland types [Note to Editor – could split into 2 tables]

Agricultural Systems		a) Rainfed extensive	b) Rainfed intensive	c) Irrigated intensive	d) Horti-culture: open	d) Horti-culture: 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	■	■				■			■	■	■	■
Intro-duction	Nutrients		■	■	■	■		■	■	■		■	
	Chemicals		■	■	■	■		■	■			■	
	Invasive species		■	■	■	■				■		■	■
	Solid waste				■						■		■
Structural change	Drainage		■	■	■	■		■					
	Conversion		■	■	■	■		■		■		■	
	Burning	■					■						

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[Box] **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".

These definitions of sustainable agriculture align with the Ramsar Convention definitions of *wise use* and *ecological character* (Resolution IX.1 Annex A), where:

- ***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.

A call for action to improve agricultural sustainability and restore wetlands

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, has broad implications for food demand and in turn agriculture production (GRFC, 2019; FAO, 2020). Despite increased food production, hunger is increasing at multiple levels (GRFC, 2019). While wetlands are a rich source of food supply for people living in developing economies, unplanned development trajectories are impacting the wetlands with drainage and reclamation for agriculture development, without realising the far-reaching consequences – changes in the ecological characteristics of wetlands, such as acute water shortages and ground water pollution (FAO 2011).

While modern agriculture supports the growing global food demand it has been a major cause of environmental degradation, including to wetlands. It is not sustainable and needs to transform to achieve the SDGs (FAO 2018). To feed a growing human population, policy makers need to promote integrated agriculture, including traditional practices, and 'sustainable intensification'.

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 and over a long time (Ramsar Convention 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). Responding to this situation will require a combination of legislative measures to ensure the ecological character of wetlands is maintained, along with incentives and 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 the wetlands.

Responding to climate change

Agriculture contributes to climate change through land use change (UNCCD, 2017; IPBES, 2019). Together, agriculture, forestry and other land use cause between 20 and 25% of global human greenhouse gas emissions (IPCC, 2014; 2019). Wetland-specific adaptation measures are required (Moomaw et al. 2018), including those that intersect with measures to ensure sustainable agriculture. These could include the allocation of water away from irrigation or other water uses to environmental flows to sustain or restore wetlands. Further, important groundwater sources could be recharged when conditions allow. The development of specific guidance is needed on adaptation measures for wetlands affected by agriculture, including an emphasis on maximising the benefits obtained from native species rather than introduced ones, the breeding of varieties more suited to changed climatic conditions in wetlands, and protection of biodiversity and developed land from large storms using nature-based solutions.

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 and national scales. In many regions of the world, river basins and the wetland ecosystems they support, are under water stress due to agricultural withdrawals. As noted in the 2020 assessment report 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.

One of the key issues is that wetlands are often not considered as part of the overall water resources network, with lack of awareness that loss of wetland connectivity can contribute to water scarcity, as well as floods. Managing and restoring wetland hydrological functioning needs to be embedded in water resources planning, working with the agricultural sector to maintain or restore environmental flows to wetlands (Barchiesi et al. 2018).

Reducing pollutants
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*". Enhancing the role of wetlands (whether natural or constructed) as nature-based solutions to reduce pollutant transfer in the environment remains important (UN Water 2018), but stronger measures to reduce pollution at source is needed, as continued inputs of pollutants will degrade wetlands.

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

Targets for transformation have been formulated in the Sustainable Development Goals, the Aichi Biodiversity targets, the Paris Climate Change Agreement, and at various multilateral forums (CBD, 2014; UNCCD, 2017; IPBES, 2019). 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.

Five principles have been previously defined to achieve sustainability in agriculture, and to meet the SDGs (FAO 2014, 2018). 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 to foster dialogue between policy-makers, wetland managers, local farmers and industry groups is considered a key strategy to transform agriculture, globally and locally, and to ensure the wise use of wetlands (Figure 6).

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
Link to case study: Audomarois wetland, France

Reduce the pressures on wetlands from agriculture, including at Ramsar sites
Link to case studies (2): Fishponds, Czech Republic and Winton Wetlands, Australia

Increase resilience of wetlands under a changing climate and greater food demand
Link to case study: Pantanal, Brazil

Transition to sustainability at catchment scales
Link to case study: Waituna Lagoon, NZ

Use market or social mechanisms to promote sustainable agriculture and wetland wise use
Link to case study: Stork-friendly rice farming, Japan

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Figure 6. Actions to transform agriculture to sustain people and conserve wetlands (adapted from FAO 2014, 2018)

What is needed to conserve wetlands

- Increase collaboration and dialogue between wetland and agriculture sectors
- Reduce the pressures on wetlands from agriculture, including at Ramsar sites
- Increase resilience of wetlands under a changing climate and greater food demand
- Transition to sustainability at catchment scales
- Use market or social mechanisms to promote sustainable agriculture and wetland wise use

Actions

1. Increase productivity, employment 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 systems

2. Protect and enhance natural resources

Stop conversion of wetlands

Restore wetlands

Improve agricultural practices to reduce impact 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 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 reduce pressure on wetlands and promote sustainable food production

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[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 constructed, 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 $kg.ha^{-1}$ of fish, but since then have increased steadily, reaching the current day yields of 450–500 $kg.ha^{-1}$ due to supplementary feeding and input of nutrients. 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 $kg.ha^{-1}$ in 2017 compared to 423-607 $kg.ha^{-1}$ 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.

[Fishpond after reduction of fish stock that promoted recovery of wetland biodiversity. Source: Martina Eiseltová]

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.

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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 bring polarised views 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 commitment from the DOC-Fonterra Living Water Partnership, $13 M was 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. Source: Living Water]

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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 agrichemicals 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.

[Rice paddies and an artificial nest tower for storks in autumn. Source: case study]

Since the 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 to balance "delicious rice production with conserving biological diversity" is being achieved.

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.

[Open grassland that supports extensive livestock agriculture, Pantanal, Brazil. Source: case study]

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.

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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 Ramsar Convention 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 program helped 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.

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

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 contaminants and find a balance between wetland biodiversity and agriculture. Market gardeners are now experimenting on using perennial species, in a wider area to increase the nectariferous resources favourable to crop auxiliaries.

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

Further Information:
Project supported by CAPSO in partnership with the Hauts-de-France Chamber of Agriculture, the Hauts-de-France Regional Federation for Defense 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 program 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 wetlands values to people - aboriginal inhabitants losing their land to European settlers for farming, followed by new settlers losing their land (1970) because of the formation of the Lake Mokoan, a dam 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. It is 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. Source: Case study]

Further Information:

Barlow T 2011. Winton Wetlands Restoration and Monitoring Strategic Plan. Winton Wetlands Committee of Management, Benalla, Victoria, Australia.

Finlayson M & Lloyd L 2020. Restoring a gem in the Murray-Darling Basin: the success story of the Winton Wetlands. The Conversation June 19, 2020. https://theconversation.com/restoring-a-gem-in-the-murray-darling-basin-the-success-story-of-the-winton-wetlands-140337

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

ENDS