

Supplementary Material

Closing the driver–response loop for halting and reversing wetland degradation and loss from agriculture

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The framing of wetlands and agriculture interactions within the Ramsar Convention

Agriculture has been linked to wetlands historically in many parts of the world. The concept of wetland ‘wise use’ distinctly recognises the multiple values provided by wetlands, including for their support to fisheries, grazing and agriculture (Ramsar Convention on Wetlands 1990; Finlayson *et al.* 2011). Additionally, the list of wetlands types under the Convention recognised “agricultural and aquacultural wetlands” as specific inland wetland types (Finlayson 2018).

In many low-income, food deficit countries, wetlands remain central to agricultural production. In Africa and in Asia a significant proportion of the economic value of wetlands is derived from agriculture (McCartney *et al.* 2010). For example, in the Inner Niger Delta in Mali approximately one million people depend on wetland cultivation, livestock grazing and fisheries for their livelihoods and wellbeing (Zwarts *et al.* 2005). Similarly, seasonally inundated wetlands are integral to the agricultural landscapes of countries such as Zambia, Malawi, and Zimbabwe, where rich, moisture-retentive soils support crops and livestock grazing during the dry season (McCartney *et al.* 2010). In Cambodia the Tonle Sap, famous for fisheries production, is also important for flood recession rice production (Matusi *et al.* 2006). In these and other examples, traditional indigenous farming systems are adapted to the natural hydrological variability that occurs in the wetlands.

The Kushiro Statement adopted in 1993 reiterated the value of wetlands to agriculture as a part of the wise use of wetlands (Ramsar Convention on Wetlands 1993). However, concerns about the impact of agriculture in terms of wetlands loss and degradation have been expressed since the Convention’s founding. The text of the final act that established the Ramsar Convention in 1971, had a specific recommendation on pollution from ‘persistent pesticides’ and urged countries to ban or severely restrict their sale and use (Carp 1971). Subsequently recommendations urging necessary political and financial actions to address agriculture-driven threats were adopted from 1990 (COP 4) onwards, mostly in line with the tone set in 1980 at COP 1 (as mentioned above). The Changwon Declaration adopted in 2008 at COP 10 is one of the many documents that call upon wetlands managers to work with development sectors, including agriculture, to ensure that the role played by wetlands is factored in national and international policies, plans and strategies (Ramsar Convention on Wetlands 2008a).

Recognition of the interlinkages of wetlands and water became more prominent in COP 6 (in 1996 and onwards), beginning with Resolution VI.23 on ‘Ramsar and Water’. This called for the integration of wetlands in river basin management (Ramsar Convention on Wetlands 1996), and was followed by resolutions addressing water allocation and groundwater (Ramsar Convention on Wetlands 2002a). This marked a distinct change in the way the relationship between wetlands and agriculture is framed within the Convention documents. The resolutions, along with the guidelines on integrated management planning (Resolution VIII.34; Ramsar Convention on Wetlands 2002b) emphasised the need to align the use of land and water within the basin and coastal zone to ensure that critical ecosystem functions and processes underpinning diverse wetlands values are not adversely affected. The new guidance on wetland management planning (Resolution VIII.14; Ramsar

Convention on Wetlands 2002c) encouraged the adoption of a diagnostic evaluation of wetland characteristics and their governing factors (including agriculture in wetlands), to be used as a basis for defining site management objectives, outcomes, and monitoring programmes. The integrated framework for wetland inventory, assessment and monitoring (Resolution IX.1; Ramsar Convention on Wetlands 2005a) provided a framework for the processes of detecting, reporting and responding to changes in wetland ecological character, including *inter alia*, those related to agriculture, both within and outside wetlands.

Resolution VIII.34 on agriculture, wetlands and water resources management stands out as a significant mention of the important role of agriculture in food security and human survival, yet calls for compatibility of agriculture practices while framing wetlands management plans (Ramsar Convention on Wetlands 2002b). The Resolution, along with the Workshop on Wetlands and Agriculture convened as part of Global Biodiversity Forum 17 (International Institute for Sustainable Development 2002), provided the backdrop of systematic scoping of agriculture-wetlands interactions. The scoping processes, which takes a multiple-response approach, called for rebalancing ecosystem services, i.e. balancing provisioning services related to the use of wetlands only as food production systems with regulating and cultural services; this can be ensured with good agricultural practices. The interdependencies between human health, food and energy security, poverty reduction and sustainable wetland management were further recognised by resolutions on biodiversity in rice paddies (Resolution X.31; Ramsar Convention on Wetlands 2008b), biofuels (Resolution X.25; Ramsar Convention on Wetlands 2008c), and avian influenza (HPAI poultry) (Resolution X.21; Ramsar Convention on Wetlands 2008d). Notably, ‘wetlands and agriculture’ was marked as the 2014 theme for World Wetlands Day. The accompanying information paper on agriculture and wetlands, in particular, presented a broadened view of the agriculture–wetlands interlinkages and identified actions for the two sectors while advocating for growth and sustainable development (Ramsar Convention on Wetlands *et al.* 2014).

The Ramsar Convention also framed wetlands and agriculture linkages in the context of broader international regimes. In 2015, the United Nations Member States adopted the 2030 Agenda for Sustainable Development reflected primarily in the 17 Sustainable Development Goals, as a blueprint for achieving a better, sustainable and just future for all (<https://sdgs.un.org/goals>, accessed 25 February 2024). Goal 2 specifically seeks to achieve Zero Hunger and calls upon the food and agriculture sector to offer solutions to eradicating hunger and poverty. The Ramsar Convention emphasised the role of wetlands in achieving SDG 2 by highlighting the value of wetlands as a source of food production, including rice and fisheries, and in providing water for irrigated agriculture. This is also addressed in SDG 6, which recognizes that 70% of global water withdrawal is due to agricultural supply chains (Ramsar Convention on Wetlands 2018a).

Agriculture is associated with a range of values ranging from instrumental (e.g. addressing hunger and nutritional security), intrinsic (e.g. conserving species diversity in production systems), and relational (e.g. agricultural systems as cultural identities and providing a sense of place). Flowing from the work within IPBES on ‘diverse conceptualisation of values of nature’, Ramsar promotes recognition of multiple values (Kumar *et al.*

2017) and promotes their integration in decision-making. This approach also supports consideration of wetlands-agricultural connections under the ‘wetlands and culture’ theme pursued through the Convention (Pritchard 2023).

A reading of Ramsar Resolutions, Guidance and related material produced over time indicates a shift in the framing of wetlands-agriculture interactions from the lens of pollution and a source of problems to one of shared opportunities and risks, thus allowing space for collaborative actions. Agriculture emerged strongly as a topic in COP 13 in 2018 and the Contracting Parties once again adopted a specific resolution on sustainable agriculture and wetlands, calling for a harmonised approach to agriculture-wetlands interactions, focusing on land and water use elements, and taking a fresh look at incentive systems and agroecological systems (Ramsar Convention on Wetlands 2018b). Yet, some elements of the wetlands-agriculture framing, mainly the use of agrochemicals (fertilisers and pesticides) and realignment of incentive systems (i.e. subsidies), were fiercely negotiated (as described later), thus defining engagement boundaries for a Convention established to deal primarily with biodiversity issues.

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Questions about the interactions between agriculture and wetlands

These questions were proposed by the Ramsar Convention's Scientific and Technical Review Panel in February 2005 within the context of responding to Resolution VIII.34 (Ramsar Convention on Wetlands 2008) and in support of the Comprehensive Assessment of Water Management in Agriculture led by the International Water Management Institute on behalf of the Consultative Group for Integrated Agricultural Research (Molden 2007), and the consortium formed to support the development of Guidelines on Agriculture and Wetlands Interactions (Wood and van Halsema 2008).

The questions presented below relate to agriculture and exclude others that referred to aquaculture and fishery activities as per the wide definition of aquaculture used by Molden (2007). The questions are presented under the following headings: agroecosystem-wetland inventory and baseline information; agricultural management practices.

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Agroecosystem–wetland inventory and baseline information:

1. How much land and water are required for future food security?
2. What is the current global extent of human-made wetlands that are related to agriculture and water resources? What are the trends in changes in extent from past to present, and how are they expected to change in future? Multiple-use systems, such as those used for both agricultural and non-agricultural purposes, should be included.
3. How many Ramsar sites or other internationally important wetlands are man-made wetlands linked to agriculture (e.g. rice fields). Analyses should be made for the different Ramsar regions.
4. What are the current and projected trends in the rates of conversion and loss of particular wetland types for agriculture, including crop cultivation? What evidence is there that clearing or drainage of wetlands for

agricultural development is the principal cause of wetland loss worldwide? Analysis should include gains in man-made wetlands through conversion of wetlands or terrestrial lands to rice fields.

5. What is the extent of conversion of traditional salinas to aquaculture (finfish and non-fish farming) sites?
6. What is the current extent of forest cultivation in wetlands? A region where such cultivation is practised in Latin America.

Agricultural management practices:

7. What is the future for wetlands with irrigation and other forms of agricultural intensification? Is there likely to be continued large-scale irrigation and what are the international, regional and local implications for wetlands?
8. Of the many forms of agriculture practised throughout the world, irrigation is considered to have resulted in the most deleterious changes to wetland character overall. What are the negative and positive effects of irrigated agriculture and its practices on wetlands and local livelihoods, including instances where wetlands are agroecosystems? For example, what evidence exists that diffuse agricultural pollution (through agrochemicals) in particular is a major source of negative effects to wetlands and their biodiversity, as well as to human well-being through impacts on ecological services and human health?
9. What future technological developments can we expect in water management in agriculture, including technologies directed at minimising agricultural water use? Particular emphasis should be given to so-called thirsty crops.
10. What are the tradeoffs between intensive irrigation and less intensive but sometimes more expansive forms of agriculture, such as rainfed agriculture, in terms of their impacts on wetlands?
11. What are the implications for wetlands in terms of their ecological character, and for the local communities that directly depend on them for their livelihoods, of the cumulative effects of large-scale adoption of small-scale technologies aimed at enhancing food production? Technologies to consider would include groundwater treadle pumps and rainwater harvesting structures.
12. Are there any agricultural practices that are sustainable in that they maintain the ecological character of the wetlands on which they depend? For example, (i) natural wetlands that are used for agriculture (European marshes used for grazing) and (ii) man-made wetlands (rice fields).
13. Which are the wetland types that are most vulnerable to conversion for agriculture and for different agricultural uses? What are the effects on wetlands of abandonment of certain agricultural practices? The abandonment of established pastoral regimes (including grazing) and conversion of pasture to other land uses should form one element of the analysis.
14. What traditional wetland landscapes are being maintained by agriculture? Which of them were agriculturally created and which depend on agriculture for their ongoing maintenance? Examples would include the semi-

natural European wet grasslands, meadows and salinas that have developed as a result of extensive management over centuries.

15. What are the impacts of shifting cultivation on wetlands?
16. To what extent do desert oases contribute to dryland agriculture and what are the ecological and livelihood implications of their modification or expansion for agricultural uses?
17. What are the implications for wetlands of land cover change? Particular attention should be given to: large scale modifications, such as conversion of agricultural land to plantation forest, deforestation, monoculture for trade; issues such as soil erosion; and regions that are considered 'water towers' (e.g. Cerrado ecoregion, Brazil). Consideration needs to be given to the interrelated impacts of land use on the hydrological cycle and the effects of climate change.
18. What water resource management mechanisms exist or are in place to ensure that the water savings from improved agricultural practices (e.g. irrigation efficiency) are allocated (at least in part) to wetlands as an environmental water allocation?
19. What are the relative merits of keeping river floodplains unregulated (or minimally regulated) as opposed to highly regulated for irrigation? Comparison of traditional flood recession agriculture and irrigated crop production. What are the possible future scenarios of these two options in the longer term with respect to livelihoods opportunities (e.g. Niger inner delta). Include accounting of the services in terms of water, nutrients and food delivered by floodplain wetlands *v.* crop production.
20. What effect does agriculture have on wetland water quality (e.g. agrochemicals such as pesticides, nutrient and sediment inputs) and conversely, what effect do wetlands have on the quality of water for agriculture? What is the extent to which wetlands process the wastewater from agriculture (natural, including floodplains in particular, and man-made wetlands). Coastal wetlands and the nearshore coastal–marine zone need to be considered, with particular emphasis on sedimentation and eutrophication.
21. How valid is the assumption that where agroecosystems function as or are wetlands (e.g. rice fields), the negative environmental impacts of agriculture may be lessened and some benefits of agriculture to wetlands enhanced?
22. What traditional (typically small-scale) sustainable systems of agriculture exist and where are they being implemented? Attention should be given to cultural landscapes and those aspects of system agriculture that represent part of the socio-cultural heritage of wetlands.
23. What is the current status of agricultural cultivation in wetlands (e.g. dambos and river valley bottoms in Sub-Saharan Africa)? What strategies are adopted by rural, poor communities to use wetlands for food production?

Of these, which ensure food and broader livelihoods security without compromising wetland ecological character?

24. Which co-operative management strategies and other actions involving local communities in wetlands characterised by multiple use have a critical role to play in fostering agricultural-wetlands interactions that are sustainable in the long-term?
25. To what extent and how do existing different systems of land tenure (including no tenure) positively and negatively affect wetlands and their wise use. Emphasis should be given to the rural poor in developing countries. Particular attention should be given to the landless people undertaking cultivation in wetlands (e.g. cultivation on river shores during low water seasons in the Mekong and Niger river systems), and to livestock and fisheries implications.
26. In what ways has agriculture been responsible for the drainage of wetlands? Consideration should be given, for instance, to the peat and mire-based wetlands of Europe and the North, peatlands in SW Uganda, and impacts of oil palm cultivation in SE Asia.
27. What are the implications for wetlands of livestock fodder production and overgrazing?
28. Certain crops are grown in areas that are inappropriate and where another crop type(s) would be more economically or environmentally sustainable. What are the impacts on wetlands of growing crops in such areas?

Groundwater:

29. How much of the future irrigation demand will be met from groundwater?
30. What are the effects of groundwater exploitation on groundwater-related wetlands, and the converse? All types of groundwater-related systems should be included (e.g. cave and other subterranean habitats, phreatic zone)? Emphasis should be on both quantity-related impacts and groundwater pollution (changes in water quality) to wetlands, and on the importance of wetlands and their ecological condition for groundwater management.

Biodiversity and ecological services:

31. What are the two-way, positive and negative implications of the interaction of the natural biota of wetlands with agricultural systems and their agrobiodiversity? What positive contributions can agriculture make to the conservation of (wild) biodiversity in managed landscapes (e.g. small dams or tank systems; rice fields)? Attention should be given to estimates of the wild biodiversity associated with wetland agroecosystems (e.g. data for rice fields, small tanks, reservoirs, genetically important wetland crops such as wild rice). It should be established whether or not the contribution made by agroecosystems to biodiversity is a greater, lesser or equivalent contribution than that of natural wetlands.

32. What are the impacts of particular agricultural plants (e.g. alien pasture species) that become weeds in wetlands, and of faunal species introduced for pest control in agricultural systems (e.g. invasive golden apple snail), on natural and man-made wetlands?
33. What are (or could be) the contribution of small restoration measures in improving agrobiodiversity and ecological services?
34. What evidence is there that irrigation or activities associated with irrigation can result in the creation or enhancement of important wetland ecosystems?
35. Wetlands are known to provide many ecological services (e.g. hydrological services, biodiversity) that agriculture is dependent upon for sustainable food production. Which services are explicitly recognised by the agricultural and water sectors and to what extent are they valued?

Climate variability and change:

36. How are increased climate variability and change expected to impact on agriculture and on water availability, and to what extent will the anticipated changes affect wetlands? An example for consideration would be shifts in the type and location of crops that can be grown.
37. Is extensification of agriculture amplifying the effects of climate change? For example, through large-scale land clearing or land-use change.
38. What are the relationships between climate change, increases in water temperatures and the effects on the plant species grown?
39. What are the climate-related implications of the promotion of agroforestry?
40. What are the agricultural impacts on wetlands in drylands in relation to drought?

Policies and institutions:

41. What is the existing suite of governance, institutional and jurisdictional models that deal with agriculture, water, and wetlands? What are their relative strengths and weaknesses, with particular attention to cross-sectoral approaches? To what extent do the agriculture, water and environment ministries work in isolation or are integrated (e.g. as in the UK). What are the implications of different levels of integration? Some attention should be directed at Ramsar Contracting Parties with national wetland policies where agricultural policies and agriculture, water and wetlands issues have been addressed. Any differences in policies and institutions for managing human-made wetlands and natural wetlands should be considered (e.g. in China human-made wetlands are given low policy importance by the ministry responsible for natural resources, and are managed under the Ministry of Agriculture).

42. To what extent are perverse incentives in agricultural and water management leading to wetland degradation? Both unintended perverse incentives from other sectors and incentives intended for agriculture should be considered. Attention should be given to, for example, electricity subsidies, subsidies for water supply (e.g. Pakistan), pricing mechanisms, and the implications for wetlands of favourable pricing of certain crops.
43. What are the implications of virtual water trade on wetlands, including in terms of the impacts of associated altered patterns in water resource demand and use, and crop production? Attention should be given to country and regional aspects that have bearing on transboundary wetlands and water resources, and to both the priorities of the importing and exporting countries. What is the potential for making changes in trade arrangements? Are there any case studies illustrating changes in trade (or pricing)?
44. How do the various international agricultural policies (e.g. sugar protocol) shape the patterns of agricultural demand, and what are the implications for wetlands, including in terms of wetland policy and its implementation, and for local livelihoods (e.g. food shortages for local people)?
45. How are consumer demands for agricultural products changing, and what are the implications of different trade regimes for local management practices? Local products, internationally exportable products, and consumer preferences should be considered.
46. What are the effects of imbalances ('non-level playing fields') in water pricing systems on agricultural practices that have an effect on wetlands? For example, in Western Europe, the agricultural sector pays less for water use than do other sectors.

Modified organisms:

47. What are the biotechnology implications and future risks associated with the introduction of genetically modified (or genetically enhanced) organisms (GMOs) (e.g. particular species, pest-tolerant seed cultivars) into wetland systems?