

Agriculture and Wetlands

Maintaining and restoring wetlands for
sustainable food production and ecosystem health

Supplementary Materials
Case study descriptions

ISBN 978-2-940786-16-9



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Required citation

Convention on Wetlands (2025) Agriculture and Wetlands: Maintaining and restoring wetlands for sustainable food production and ecosystem health. Supplementary Materials: Case study descriptions. Gland, Switzerland: Secretariat of the Convention on Wetlands. DOI: 10.69556/strp.tr13.25.supp.

ISBN: 978-2-940786-16-9 (PDF)

DOI: <https://doi.org/10.69556/strp.tr13.25.supp>

Cover photo: Tom Fisk

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Published by the Secretariat of the Convention on Wetlands.

Agriculture and Wetlands

Maintaining and restoring wetlands for sustainable food production and ecosystem health

Supplementary Materials

Case study descriptions

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Background

This supplementary material accompanies Technical Report No. 13 - Agriculture and Wetlands: Maintaining and Restoring Wetlands for Sustainable Food Production and Ecosystem Health, developed by the Scientific and Technical Review Panel (STRP) of the Convention on Wetlands under Task 3.3.

Task 3.3 was set up in response to Resolution XIV.14 and addresses Target 14 of the Fourth Strategic Plan (2016–2024), which aims to provide stronger scientific and technical guidance for the sustainable use of wetlands. The task specifically focuses on agricultural catchments, where unsustainable farming practices are a key driver of wetland degradation.

The main report presents a synthesis of scientific knowledge and policy experience on agriculture–wetland interactions. It outlines the direct and indirect pressures that agricultural systems exert on wetland ecosystems and offers strategic responses based on five interlinked sustainability principles: (1) improving the efficiency of resource use, (2) conserving and restoring wetland ecosystems, (3) supporting rural livelihoods and equity, (4) building socio-ecological resilience, and (5) strengthening governance and cross-sectoral coordination.

One central component of the report is a set of 18 case studies, each analysed according to these five principles to demonstrate the range of challenges and responses in different ecological and institutional settings.

Purpose of the supplementary materials

This supplementary materials provides the full descriptions of the 18 case studies referenced and summarised in the main report. These case studies illustrate agriculture–wetland interactions across all the Convention on Wetlands regions and cover a broad diversity of wetland types, including rivers, floodplains, peatlands, mangroves, rice paddies, and constructed wetlands, and agricultural systems, including rainfed and irrigated crops, livestock, and aquaculture. Each case includes information on site characteristics, the nature of wetland degradation or pressure, governance and institutional context, sustainability challenges, and actions taken.

In addition to site-level detail, the supplementary materials document the evaluation of each case study using the five sustainability principles. These assessments provide insight into the trade-offs, barriers, and enabling conditions that influence the effectiveness of different interventions. The supplementary materials also complements the comparative analysis in the main report by allowing readers to access the full documentation of case-specific experiences.

Together, the supplementary materials and main report provide a knowledge base to support Contracting Parties and other stakeholders in identifying feasible options for managing wetland–agriculture interactions in support of wetland conservation, food production, and climate and biodiversity goals. This material is intended for use in national planning, catchment-scale wetland management, agricultural policy development, and implementation of the Convention.

Case 1. Sustainability options for extensive and intensive agriculture in Yala and Anyiko papyrus wetlands, Kenya

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Site details

Item	Details
Site name	Yala and Anyiko wetlands
Contracting Party/Country	Kenya
GIS Coordinates	Yala wetland: longitudes 34°02'0"E and 34°10'0"E and latitudes 0°04'0"S and 0°04'0"N Anyiko wetland: longitudes 34°16'30"E and 34°18'0"E and latitudes 0°16'0"N and 0°14'30"N
Site ID	N/A
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	Yala wetland: 20,756 ha Anyiko wetland: 158 ha
Wetland type	Rivers, streams, floodplains
Agricultural system type	Rainfed extensive, intensive; Irrigated

Main key message

For small-scale farmers in papyrus wetlands in western Kenya, support to increase farm productivity and livelihoods, as well as provision of sustainable alternative livelihoods opportunities, would contribute to reducing conversion of natural wetlands to cropping. This could be achieved through a multi-sectoral governance approach and increasing awareness on existing laws and regulations. For large-scale intensive cropping, establishment of Corporate Social Responsibility activities aimed at reducing environmental impacts and providing alternative livelihoods to local communities would reduce pressure on the wetland for cropping.

The challenge presented by food production in relation to papyrus wetlands

Yala and Anyiko wetlands are both papyrus (*Cyperus papyrus*) dominated inland wetlands in Kenya. The large Yala wetland system (20,756 ha) consists of three permanent satellite freshwater lakes (Kanyaboli, Sare, and Namboyo), one human-made reservoir and a permanent extensive floodplain marsh. Anyiko wetland is a relatively small (158 ha) riverine permanent marsh. Despite their size difference, they face the same challenge: conversion to agriculture.

Yala wetland

The agricultural systems in Yala wetland are: (1) small-scale, extensive rainfed systems (largely organic or without fertilizer use) practiced by local communities; and (2) large-scale intensive rainfed systems with high fertilizer (100 kg/ha NPK for planting and 100 kg/ha CAN for top dressing) and pesticide use, operated by a private investor. Due to climate variability, irrigation to supplement rainfed cropping in the large-scale system is planned in the near future. In the small-scale system, various food crops are grown for subsistence and local markets. In contrast, in the large-scale intensive system sugarcane (formerly rice paddy fields) is grown for commercial purposes.

Land conversion to these agricultural systems is driven directly by anthropogenic structural and physical regime changes. Since the 1960s, Yala wetland has undergone surface drainage by canals and removal of wetland vegetation to allow planting of sugarcane, rice, maize, sweet potatoes, cassava, bananas, coco yams, and vegetables. Physical regime changes included construction of a dyke along River Yala to control flooding in the areas already converted to cropping; construction of a reservoir and a weir in River Yala to regulate water supply to the commercial cropping area; control of water flowing into and out of Lake Kanyaboli using sluice gates to reduce inundation in the downstream areas of the lake and allow further land conversion to cropping; upstream diversion of the seasonal river, Hwiro, away from the cropping area in the wetland; and lastly construction of a retention dyke across the outfall of Lake Kanyaboli to control flooding in the downstream areas of the lake and to connect local communities across the wetland (Odhengo et al., 2018). The impacts of introduction drivers (high fertilizer and pesticide use) in the large-scale intensive rainfed sugarcane cropping on the wetland remain undocumented.

Apart from the direct drivers of change, indirect drivers related to wetland governance and poverty among the local communities have influenced decision-making on wetland conversion to cropping. Traditionally, local communities perceived the wetland as community land. This has influenced decision-making on its access and use for small-scale extensive cropping, leading to a loss of 11.5% of the wetland from 1960 to 2014 (Muoria et al., 2015; Odhengo et al., 2018). Also, the perception of “communal ownership” is causing conflicts on rights to land access, use, and benefit-sharing between the local communities and the private investor who, through a leasehold from the national government, is using 9.4% of the wetland for intensive cropping. There are also conflicts between local communities and the local and national government on gazettement of Lake Kanyaboli and parts of the marsh as a National Reserve (legal notice No 158 of 2010) (Odhengo et al., 2018). Over 80% of the local communities within and around the wetland have an income below \$1 per day (Nature Kenya, 2011), which increases the pressure to drain more land for agriculture as the population increases. The Yala Wetland Land Use Plan, developed in 2018 by an Inter-County Technical Committee with participation of local stakeholders, county, and national government agencies, advocates for balanced development between agriculture and conservation and projects that by 2050, 31% of the wetland will be used for subsistence and commercial crop cultivation (Odhengo et al., 2018).

Agricultural production in the wetland has contributed to improved food security and livelihoods of the local communities. The conversion of the wetland for sugarcane production has also boosted local sugar supply to meet the deficit in the country. However, all these are short-term gains at the expense of other ecosystem services in the long term. Yala wetland is an internationally recognized Key

Biodiversity Area that hosts many globally and nationally threatened species of fish, birds, and mammals. It is also providing valuable ecosystem services such as carbon storage, provisioning of water for domestic use and livestock, papyrus for the handicraft industry, fish for food from its three lakes and reservoir, and livestock grazing area. The wetland also plays a significant role in buffering Lake Victoria from upstream basin pollution by retaining nutrient, sediments, and other pollutants from the catchment (Muoria et al., 2015). As the unsustainable land conversion to cropping continues, various direct users of the wetland (such as papyrus artisans, fisherfolk, livestock farmers, and domestic water users) are likely to lose their livelihoods supported by the present wetland ecosystem services. These losses, however, will also affect other indirect beneficiaries (e.g. lake fishers, consumers/users of wetland products along the consumption footprint or people using good quality surface water), indicating a likelihood of a ripple effect and a larger impact beyond the immediate riparian communities. The local governments (the County Governments of Siaya and Busia) are also likely to lose revenue generated, present and future anticipated, from yet-to-be-developed ecotourism in the wetland. This is inevitable if the wetland is continuously and progressively converted to cropping, leading to the loss of natural habitats and biodiversity. The only beneficiaries are likely to be the private investors and small-scale farmers, in the short term, as more land becomes available for intensive cropping.

Anyiko wetland

The agricultural systems in Anyiko wetland are: (1) small-scale, extensive (largely without fertilizer use), rainfed cropping systems; and (2) small-scale, semi-intensive irrigated cropping systems (in the farmer-led Anyiko irrigation scheme) with high water use and low to medium fertilizer use (0-120 kg/ha DAP for basal, 0-120 kg/ha CAN for the first, and 0-120 kg/ha for the second top dressing). Both systems are practised by the local communities. In the extensive rainfed system, a variety of food crops is grown for subsistence and local markets whereas in the irrigated system rice is grown for commercial purposes.

The anthropogenic structural and physical regime change in the wetland (land conversion to agriculture) is driven by indirect drivers like wetland governance and the socio-economic status of households in the communities. For the extensive cropping, structural changes have occurred through surface drainage by canals and the removal of wetland vegetation and replacement with vegetables, sugarcane, coco yams, sweet potatoes, and maize. In the semi-intensive system, surface drainage and vegetation removal were accompanied by rice planting and water flow diversion from the wetland to the Anyiko irrigation scheme (Ondiek et al., 2020). Traditionally, households whose upland farms are adjacent to the wetland or who had converted some parts to cropping in earlier years, have assumed rights to land access and use for cropping. Also, households that have limited alternative sources of livelihood and are not harvesting papyrus for handicrafts are likely to use the wetland for cropping. These drivers of change have led to fragmentation and loss of 55% of the wetland since 1966 (Ondiek et al., 2020).

Agricultural development in Anyiko wetland supports the livelihoods of the local communities, but as unsustainable agriculture continues, other ecosystem services from the wetland such as papyrus for handicrafts, water for irrigation, and carbon storage will decline or be lost (Ondiek et al., 2025). Additionally, productivity of cultivated wetland areas is declining. As a result, livelihoods of papyrus artisans and the farmers in the long term will be jeopardized when the entire wetland is converted to cropping.

Actions or opportunities to make the system more sustainable

a) Options for increasing resource use efficiency

In the small-scale rainfed systems there is generally no irrigation water management or application of fertilizers or pesticides, so options for increasing resource use efficiency are limited. In the small-scale irrigated systems, water for rice irrigation is abstracted from the wetland during high flows (rainy season) via a canal. In the irrigation scheme, the feeder and drainage canals are dilapidated, leading to inefficient water use. Improving the irrigation infrastructure and water management would lead to more effective irrigation and reduction in water diversion from the wetland. Rice farmers do not use rice straw and husks produced after harvesting and milling, respectively. Rice straw could be used by the farmers as livestock feed or sold (by connecting rice farmers to markets) to livestock farmers (rice-livestock integrated farming). Rice husk could be used as feed ingredient in poultry farming or sold to poultry farmers (rice-poultry integrated farming) as bedding and for floor insulation which could later be used as soil amendment. These options could be one of the opportunities to provide the much-needed alternative sources of livelihoods for those cropping in the wetland, thus contributing to reducing pressure on the wetland for cropping. Embracing these opportunities would require building the farmers' knowledge about these techniques and connecting them to markets. In the large-scale, intensive systems fertilizer and pesticide use could be reduced or limited to some maximum levels to avoid runoff into the wetland. Foreseeable impacts of irrigation on the wetland could be reduced by employing irrigation systems that maximize on efficient water use.

b) Protecting wetlands and mitigating pressure/impact on wetlands

The 'Key Biodiversity Area' recognition for Yala Wetland and the proposed designation of Lake Kanyaboli and some parts of the marsh as a national reserve are opportunities to protect the wetland from further degradation and loss due to cropping. In national reserves, the primary activities are usually ecotourism and research, and other activities are only allowed under specific conditions. However, there is opposition to a more formal protected status from local communities, and enforcement will be a challenge. Therefore, more realistic opportunities for sustainability are in the 'Responsible and effective governance and institutions' category. If the protected status would be realized, then restricting local communities and private investors from cropping in designated national reserve areas and restoring the degraded areas would be needed.

c) Supporting rural livelihoods, equity, and social well-being

To reduce pressure on the wetland for cropping, the NGO Nature Kenya is promoting alternative livelihoods options (such as aquaculture, poultry farming, bee keeping) to operators of the small-scale rainfed systems in Yala wetland by providing fish feeds, fingerlings, bee hives, and chicks to the local communities' youth groups. There are also efforts to establish a cottage industry for handicrafts to stimulate papyrus value addition as an alternative source of livelihood. Another option is improving crop productivity in upland farms through agricultural extension services to improve food security and reduce pressure on the wetlands. For the small-scale irrigated systems, provision of alternative sources of livelihoods and productivity improvement through agricultural extension for the rice farmers would also be options to achieve more sustainability.

d) Building resilience in people, communities, and ecosystems

For all small-scale farmers, agricultural extension services could support farmers in applying more integrated approaches and enhance nutrient cycling. This could increase productivity of wetland farming as well as prevent more conversion of the wetlands.

e) Responsible and effective governance and institutions

For papyrus wetlands like Yala and Anyiko, a multi-sectoral approach is critical to create awareness among the local communities on land tenure and land rights in the wetlands, and management of water resources, wildlife conservation and fisheries (especially for the Yala wetland), and to implement the formal governance system in the wetlands by the relevant county based national government agencies in charge of the implementation of existing policies on water resources (Water Resources Authority and National Environment Management Authority), land (the National Lands Commission), wildlife conservation (Kenya Wildlife Service), and fisheries (Kenya Fisheries Service). This would also mitigate conflicts on land access, use, and benefit sharing between local communities and the private investor in the Yala wetland, and between local communities and county based national government agencies on gazettelement of Lake Kanyaboli and parts of the marsh as a National Reserve. Review, approval, and implementation of the proposed Yala Wetland Land Use Plan should be a pillar of this multi-sectoral approach. Such an approach would include development of local community-based institutional arrangements to promote sustainable wetland management including by-laws, zoning, and others.

For all small-scale farmers, support and incentives from county governments to improve farming methods and increase productivity can contribute to curbing further wetland conversion to cropping. For the irrigated systems, the County government should allocate budget for rehabilitation of irrigation infrastructure in the Anyiko irrigation scheme in its County Integrated Development Plan. For all efforts to improve small farm productivity, care should be taken that fertilizer application matches crop needs to prevent water pollution in the wetlands.

For small-scale, rainfed farmers, provision and upscaling of alternative livelihoods by the county governments could contribute to alleviate pressure on wetlands.

The large-scale intensive farming operations could develop Corporate Social Responsibility activities aimed at providing alternative sources of livelihoods to the local communities and collaborate with local governments in this area. The potential for the private sector to collaborate with and support local communities and other key stakeholders could be developed further.

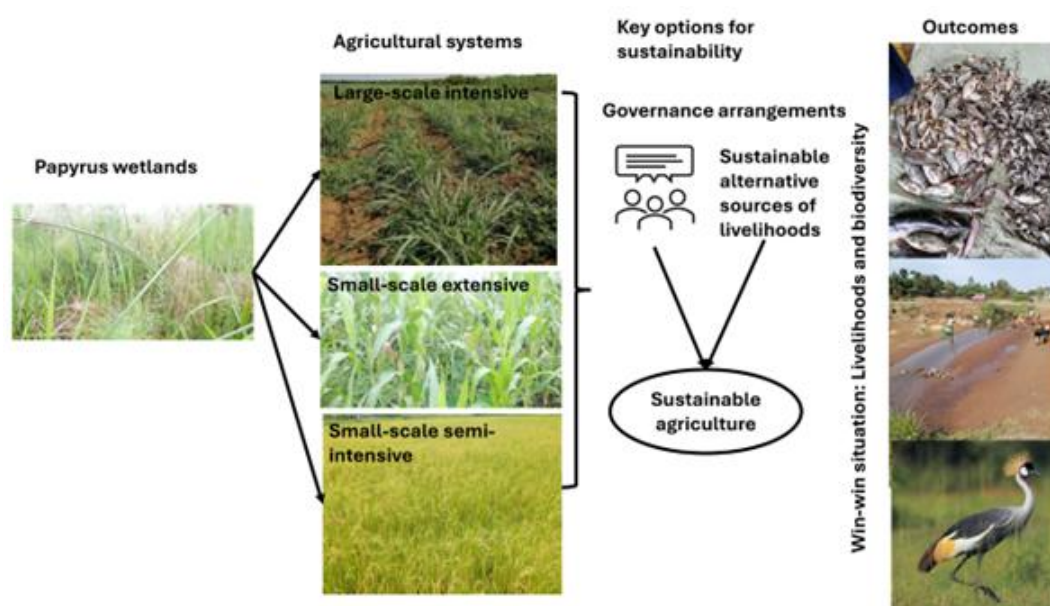


Figure 1: The agricultural systems in Yala and Anyiko papyrus wetlands and key options for sustainability leading to both livelihood support and biodiversity conservation. (© Risper Ajwang' Ondiek)

Conclusion

Pathways to sustainability in these papyrus wetlands without formal protection status are controlled by decision-making at local and national levels in collaboration with the local communities and the private investor (Figure 1). For small-scale rainfed cropping, creating awareness among the local communities on land tenure and land rights in the wetlands and enforcement of existing laws and regulations through a multisectoral approach would be effective in making agriculture more equitable, productive and sustainable. For small-scale irrigated cropping, allocation of budget by the local government in the County Integrated Development Plan to rehabilitate irrigation infrastructure, and implementation of regulations on water abstraction by the Water Resources Authority is required. For both small-scale agricultural systems, intentional actions by the local governments in collaboration with the farmers to provide and upscale alternative sources of livelihoods and improve productivity of both wetland and upland farms through agricultural extension services would be key in reducing pressure to convert more wetlands to cropping. In the large-scale intensive rainfed cropping, the establishment of Corporate Social Responsibility activities by the private investor aimed at limiting environmental impact and providing alternative sources of livelihood to the local communities would reduce pressure on the wetland for cropping.

References

- Muoria P, Field F, Matiku P, Munguti S, Mateche E, et al. (2015) Yala Swamp ecosystem service assessment. Nature Kenya – the East Africa Natural History Society, Nairobi.
- Nature Kenya (2011) Yala Swamp Socio Economic survey. Nature Kenya, Nairobi.
- Ondiek RA, Vuolo F, Kipkemboi J, Kitaka N, Lautsch E, et al. (2020) Socio-economic determinants of land use/cover change in wetlands in East Africa: a case study analysis of the Anyiko Wetland, Kenya. *Frontiers in Environmental Science* **7**, 207.
- Ondiek RA, Hayes DS, Kinyua DN, Kitaka N, Lautsch E, et al. (2021) Influence of land-use change and season on soil greenhouse gas emissions from a tropical wetland: A stepwise explorative assessment. *Science of the Total Environment* **787**, 147701.
- Odhengo P, Matiku P, Muoria PK, Nyangena J, Waweru P, et al. (2018) Yala Delta Land Use Plan. Siaya and Busia County Governments, Siaya and Busia, Kenya.

Case 2. Diverse perspectives on sustainable agriculture in Merja Sidi Ameur, a temporary wetland in a semi-arid landscape of the Gharb plain, Morocco

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Site details

Item	Details	Remarks
Site name	Merja Sidi Ameur	Dried wetland according to 1956 Dahir (27 August) on the Rharb's reclaimed merjas
Contracting Party/Country	Morocco	
GIS Coordinates	Latitude: 34°27'14.75"N Longitude: 6°19'48.14"O	
Site ID	N/A	
RIS last updated	N/A	
RIS source	N/A	
Surface area of case site (ha)	6,900	
Wetland type	Rivers, streams, floodplains	
Agricultural system type	Rainfed intensive; Irrigated	

Main key message

Merja Sidi Ameur, a temporary wetland, dried since the early 20th century, supports agricultural activities like grazing and crop cultivation. Irrigation water access is limited, necessitating deep wells, or using drainage water from nearby paddy fields. Sustainable wetland-agriculture could be achieved by restoring the wetland's function and maintaining agricultural and cultural activities.

The challenge presented by food production in Merja Sidi Ameur

Merjas are temporary wetlands in the Gharb plain (~300,000 ha) within the Sebou River catchment in a semi-arid region of Morocco. The Sebou catchment covers less than 10% of Morocco's surface area yet provides one-third of its water resources. Due to sediment accumulation, the beds of the Sebou and its tributaries lie slightly elevated, slowing sediment-laden flows and increasing the area's flood vulnerability. This configuration explains its vulnerability to flooding. Over the 20th century, the Gharb plain was drained for agriculture, now supporting about 180,000 ha of irrigated land, with 30,000 ha of temporary wetlands remaining.

Merja Sidi Ameur is a temporary wetland subject to intricate socio-economic and ecological dynamics. Merja Sidi Ameur retains water from overflowing tributaries (Rdom and Beht) of the main Sebou River watercourse and also from local rainfall. Historical studies have highlighted the presence of plant communities specific to merjas, such as the aquatic grouping of ranunculus, reeds and bulrushes (Le Coz, 1964). However, drainage has led to the degradation and even disappearance of this flora.

The significant alterations to the merja's physical regime, consisting of extensive drainage works and dam construction, were intended to support national food self-sufficiency, but have also led to a degradation of ecological character and biodiversity. The disappearance of much of the flora and fauna has transformed the merjas into areas primarily focused on agriculture. The landscape is now more arid, which has been exacerbated by an on-going drought since 2018. Local communities do not view the merjas as a wetland anymore but as productive land that needs access to irrigation water and effective water management to prevent waterlogging during rainy periods.

The merja faces challenges from widely different management perspectives, including those of local communities, agricultural institutions, hydraulic institutions, and the Ministry of Interior. Some agricultural institutions view it as a wasteland, only useful for agricultural use, while others recognize its value as a biodiversity hotspot. Local communities consider it a vital hydrosocial territory for community life. These diverse views complicate achieving consensus on sustainable management approaches.



Figure 1. Cattle grazing area at the merja Sidi Ameur. (©Choukrani, 2021)

Agricultural activities, such as irrigated and rainfed farming are prevalent. In winter, rain-fed crops like sugar beet, wheat, barley, and alfalfa benefit from rainfall but are at risk of soil waterlogging. Farmers adapt by planting catch-up crops, such as sunflowers, if winter crops fail. When soil is waterlogged, wheat is mowed for livestock fodder, highlighting the synergy between crops and livestock. Farmers consider livestock farming essential and profitable, with lower flood risk (Figure 1). Irrigated crops (melon, tomato, artichoke, maize, rice) depend on water access (Figure 2). Some farmers use drainage water of paddy fields to irrigate. As the surface water is salty, other farmers - often tenants - have set up deep boreholes (up to 120 m deep) to irrigate their crops. Local farmers appreciate the entire merja for its agropastoral ecosystem services, while institutional stakeholders only recognize its agricultural potential within publicly irrigated perimeters.

The conflicting land claims and management views among stakeholders highlight the complex dynamics at play, raising questions about the legitimacy of access and usage. While local authorities and agricultural and hydraulic institutions prioritize agricultural interests and flood protection, the

ecological and cultural dimensions remain underrepresented in the debate. The lack of concern for biodiversity, particularly among environmental institutions and ecologists, is likely due to the reduced frequency of submersion and the extensive agricultural activities and irrigation that are taking place in the merja. Balancing development and conservation in Merja Sidi Ameer is a critical on-going debate, necessitating the engagement of all stakeholders to develop sustainable management practices and ensure the ecological integrity and multifunctionality of the merja.



Figure 2. Irrigated maize in the merja Sidi Ameer. (©Choukrani, 2021)

Actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

The Gharb region's climate and soil conditions make it suitable for cultivating industrial crops, such as sugar beet and sugar cane, along with conventional crops like cereals and vegetables. These high-yield crops often require intensive fertilizer and pesticide applications to boost productivity and protect against plant diseases. While there are no specific studies on fertilizer and pesticide use in the Merjas, fieldwork observations and surveys indicate that local farmers do apply them. More broadly, research in other areas of the Gharb plain has demonstrated a high use of fertilizers and pesticides that are a primary cause of groundwater contamination.

Irrigation of crops requires the use water resources, which some farmers obtain by using drainage water from paddy fields. However, due to the salinity of the water, others have resorted to deep boreholes, potentially affecting groundwater reserves.

Since the irrigation perimeter is privately managed, farmers operate independently, and the state provides minimal oversight or support. Although most farmers already use drip irrigation to manage water more efficiently, there is still a need to increase awareness about sustainable agricultural practices to further minimize environmental impacts. For example, training programs focused on optimizing drip irrigation and reducing chemical could enable farmers to enhance resource efficiency and protect groundwater quality and quantity.

b) Protecting wetlands and mitigating pressure/impact on wetlands

Protecting wetlands is crucial for mitigating environmental pressures and preserving biodiversity. Sites like Merja Zerga (7,300 ha) and Merja Sidi Boughaba (650 ha), located about 40 km northwest of the central area (of the Gharb plain), are permanent wetlands protected under the Convention

on Wetlands. Another temporary wetland, Merja Bokka, despite being a Site of Biological and Ecological Interest (SIBE), is marginalized and requires similar attention.

The emphasis on permanent wetlands has led to limited ecological studies and a lack of conservation efforts for temporary wetlands, including the central merjas like merja Sidi Ameer. Research on the merja Sidi Ameer noted the lack of legal protection status for not only the merja itself but more generally for temporary wetlands in Morocco. The delay in legislation is enhanced by the intermittent hydrology and the complex situation of land tenure. Responsible governance would involve developing policies, laws and implementation mechanisms that safeguard such unique wetland ecosystems and the integrated livelihood practices dependent on them. For example, establishing merja's protection could involve designating such areas under frameworks like the Convention on Wetlands, which promotes the conservation and sustainable use of wetlands.

c) Supporting rural livelihoods, equity, and social well-being

The merja Sidi Ameer (whether perceived as a seasonal wetland, as a productive land, as a buffer zone, or as a conflictual land) plays a vital role in supporting local communities by providing employment and income through farming activities, including crop cultivation and livestock rearing. Sustaining these integrated production systems is crucial for the livelihoods of the local communities who depend on the merja. Local communities and state institutions are in conflict regarding access and usage rights of the merja. The State has initiated meetings to address merjas management and land tenure issues and find common ground, but so far (2023) no agreement has been reached. Resolving these conflicts requires recognizing traditional land-use practices and striving for fair management, ultimately fostering equity among all stakeholder groups.

The Merja Sidi Ameer also holds cultural importance for local communities, offering a sense of connection and belonging. Adopting management strategies that respect these cultural values can significantly enhance the social well-being of the communities. Additionally, involving locals in decision-making processes strengthens social cohesion by aligning sustainable wetland use with community interests.

d) Building resilience in people, communities, and ecosystems

The resilience of the local communities in the merja Sidi Ameer stems from the integration of crop cultivation and livestock rearing, which diversifies income sources and helps communities cope with climate variability. This resilience is crucial for adapting to climate risks like floods and droughts, with merjas providing natural flood regulation that protects downstream areas.

e) Responsible and effective governance and institutions

To manage the competing claims over the merja Sidi Ameer lands, effective governance mechanisms are essential. A legal protection status for temporary wetlands, e.g. under the Convention on Wetlands, could be part of this (see under b.). Sustainable management also requires collaboration across multiple sectors—agriculture, livestock, water resources, and environmental conservation. This could involve joint planning and decision-making, inter-transdisciplinary research initiatives, and integrated policy development. Coordination by a neutral entity is essential, as the conflicts involving the merjas involve multiple stakeholders and have been unresolved for years. Developing integrated policies and legal frameworks that protect seasonal wetlands such as the merja Sidi Ameer and support local livelihood practices (cultural and agricultural) is crucial for sustainable development.

Integrating these considerations can help develop a more comprehensive and sustainable management plan that not only enhances the ecological functions of the merjas but also supports the economic wellbeing of the communities. By doing so, management strategies can align more closely with the diverse needs and values of the community, ensuring that the merjas continue to provide multiple benefits for all stakeholders involved.

Conclusion

While all sustainability criteria are important for the long-term viability of Merja Sidi Ameur, focusing on governance is particularly impactful. Effective governance can serve as a unifying framework that addresses diverse challenges, including supporting local livelihoods, enhancing resilience, protecting biodiversity, and increasing resource efficiency. By advancing collaborative decision-making, establishing legal protections, and integrating cultural values, responsible governance can help resolve ongoing management issues. Prioritizing governance lays the groundwork for a sustainable approach that aligns the ecological, economic, and social needs of the Sidi Ameur merja, ensuring that all criteria work together to support a balanced and resilient ecosystem.

References

- Choukrani H, Imache A, Kemmoun H, Kuper M, Hammani A, et al. (2023) Question agraire, question hydraulique : Mise en débat de l'avenir des merjas de la plaine du Gharb, Maroc. *Alternatives Rurales* **9**. <https://doi.org/https://doi.org/10.60569/9-a7>
- Choukrani H, Kuper M, Hammani A, Lacombe G, Taky A (2023) Visions contrastées des services écosystémiques des zones humides saisonnières du Gharb, Maroc. *Cahiers Agricultures* **32**, 2. <https://doi.org/10.1051/cagri/2022031>
- Choukrani H, Lacombe G, Zwarteveen M, Kuper M, Taky A, Hammani A (2023) Sense-making and shaping of temporary wetlands: A socio-hydrological analysis of dichotomous ontologies of merjas in Morocco. *Journal of Hydrology* **627**, 130434. <https://doi.org/10.1016/j.jhydrol.2023.130434>
- Floodplain Structuring Action Morocco Project (2022) Final Report - Foncier zones inondables Maroc - COSTEA (comite-costea.fr)

Case 3. Sustainable rice production in restored urban rice paddy fields, Colombo, Sri Lanka

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Site details

Item	Details	Remarks
Site name	Colombo Ramsar City	City accreditation in 2018
Contracting Party/Country	Sri Lanka	
GIS Coordinates	6°50'57.42"N, 79°57'49.75"E	
Site ID	N/A	
RIS last updated	N/A	
RIS source	N/A	
Surface area of case site (ha)	32 ha	Part of the Colombo Wetland Complex (1900 ha)
Wetland type	Agricultural wetlands (rice paddy)	
Agricultural system type	Irrigated	

Main key message

Paddy fields as human-made wetlands play an important role in ensuring food security, recharging groundwater and regulating floods in highly modified urban landscapes such as Colombo, Sri Lanka. This case study provides an example of the restoration of abandoned urban paddy lands through diverse mechanisms to improve biodiversity, ecosystem services as well as food security.

The challenge presented by food production in relation to urban wetlands in Colombo

The urban wetlands of Colombo are a collection of open water bodies, marshes, woodlands, paddy fields, and a network of canals and is referred to as the Colombo Wetland Complex (CWC). A study that identified a catchment of 227 km² and a study area of 121 km² reported that only a 20% of wetlands are remaining and many were paddy fields that were either active or abandoned.

Rice is the staple food of the country's population, contributing to nutritional needs through the supply of energy, protein and fat (Figure 1). It is estimated that over one-third of Sri Lanka's agricultural land is devoted to rice production, and although urban rice paddy cultivation is relatively small, it is an important source of food for the urbanites, and an income-generating activity for the low-income groups. During the Covid pandemic, it was a boon for women to source food for their

families, especially when movements were restricted. Since the pandemic, the planners feels that these urban food production systems should be supported and encouraged as a risk mitigation strategy and enabling greater preparedness to face calamities.

Rice cultivation in Sri Lanka dates back to the evolution of the country's hydraulic civilisation in 500 BCE where a number of major and minor reservoirs were built to enhance water storage and irrigate paddy land. However, these urban wetlands in the metro Colombo region (South Western Region) depend on rainwater that is collected in a vast network of canals and storage ponds that are interconnected.



Figure 1. Rice paddy fields in Colombo Wetland Complex. (© Padmini Perera/Manosha Welikala)

The urban paddy rice areas were once part of the periurban landscape and privately owned. Generations have grown rice and vegetables on these lands, and by law, they cannot convert them to any other form. However, over time and with urbanization, a considerable proportion of urban paddy land has been abandoned due to labour shortages, pest/disease attacks, high costs and a lack of profitability. With the urban expansion, the parcels of paddy land have reduced in size due to infilling and encroachment. Despite this shrinking of paddy rice areas in the Colombo metropolitan region, their ecosystem services in terms of flood mitigation, agriculture production, livestock rearing, and herb and medicinal plant collection are enjoyed by urbanites and low-income communities. Retention of floods by the Colombo wetlands complex is one of the most valued ecosystem services with wetlands retaining 39% of floodwater during high precipitation events (Hettiarachchi et al. 2014b; McInnes and Everard 2017). Revitalising rice paddy cultivation has therefore been embedded in the flood mitigation strategy (Signes 2016).

More than 87% of the total wetland area of Colombo Wetland Complex provides food to the local communities through diverse means and thus, contribute to food security across the city (Signes 2016). As a result of abandonment, paddy lands experienced natural succession where the ecosystems changed from paddy to herb dominated wetlands (Figure 2). In some instances, these wetlands have converted entirely to woodlands dominated by invasive alien species such as *Annona glabra* (pond apple). These human induced alterations in wetland ecology have resulted in increased risk from floods as the storage capacity of Colombo wetlands has decreased by approximately 40% (Weerakoon et al. 2023).



Figure 2. Abandoned paddy lands overgrown with herbs. (© Padmini Perera/Manusha Welikala)

It is imperative that all Colombo wetlands are either conserved and/or restored to prevent the surpass of the tolerable threshold of 1% GDP under expected climate change events (Rozenberg et al. 2015). Restoration is important for vital ecosystem services, including provisioning of food, flood retention, and habitat provision. The paddy lands in the Liyanagoda and Kottawa North agrarian development divisions of the Kottawa Divisional Secretariat constitute 32 ha of which 12 ha were estimated to have been abandoned for a period of 5-10 years. Lack of labour, prohibitive costs of cultivation, and the need to build houses were some of the reasons given for abandoning the plots. During 2019, the Department of Agrarian Development (DAD) in Maharagama took the initiative to restore 12 ha of abandoned paddy land by commencing direct discussions with 15 farmers in two farmer organizations that held legal rights to cultivate rice in the area. Under this special project the government provided fertiliser, seed paddy, canal rehabilitation, and training and knowledge management. Funds were not allocated to individual farmers. The extension officers provided necessary resources and encouraged farmers to recommence agricultural activities through meaningful one-on-one conversations on the benefits of self-sufficient farming for food security and good health. Given that Colombo Wetland Complex involves multiple stakeholders, including the local farmers, there was a need for enhanced coordination and commitment to restore and maintain the ecological character of the selected paddy sites.

Actions or opportunities for actions to make urban rice cultivation more sustainable

a) Options for increasing resource use efficiency

The DAD encouraged farmers to use only organic fertilizers but provided them with both chemical and organic fertilizers with application instructions. For one crop cycle of six months, organic fertilizers included HS Eco fertilizers (200 kg/acre), biofilm biofertilizers (4 L/acre), and organic liquid fertilizers (6 L/acre). These were supplemented with a combination of chemical fertilizers applied at a relatively reduced rate of 116 kg/acre. Traditional methods such as the application of rice husk charcoal (produced by incomplete burning of rice husk) are also used to improve soil fertility, strengthen paddy seedlings and improve resource use efficiency. Both natural remedies (e.g. Neem, *Azadirachta indica* essence) and synthetic pesticides/weedicides (e.g. Actara, Marshall 20) are used to control pests and

prevent diseases. The farmers are urged to regularly monitor crop health for early diagnosis and prevention of the spread of pest and disease attacks.

Canal rehabilitation was done by the irrigation division of the DAD and also the Sri Lanka Land Development Corporation, especially where canal widening was needed. The idea was to hold more water to reduce the rate of flow reaching downstream and allow more water for cultivation purposes. The overall plan also considered flooding that had taken place a few years back when the parliament complex went under water. As the paddy land is rainfed, there was no specific need for pumped irrigated water for farming, except for a few plots that did not receive water directly from the canals. There were no exceptional water conservation practices employed by the farmers and there is potential agrochemical effluents runoff to nearby waterways. Some farmers (20%) integrated other crops by cultivating various vegetables and fruits (e.g. okra, corn, beans, banana) on the banks of the paddy farm.



Figure 3. Cleaning and excavation of degraded paddy fields and canals.
(© Padmini Perera/Manosha Welikala)

b) Protecting wetlands and mitigating pressure/impact on wetlands

The key component in restoring paddy lands include clearing woody vegetation and cleaning the canal system to reinstate and revitalise the hydrological network. The Provincial Irrigation Department supported the identification of main canals that should be prioritised for restoration and provided machinery and other resources for cleaning and excavation (Figure 3). The resulting canal network provided the water required for nurturing the paddy land back to life. Further, DAD has initiated a program to digitize and register farmlands, including paddy land, which will enhance land demarcation and ownership rights. In urban areas where encroachment and land conversion are rampant, having accurately demarcated plots can reduce threats and resource use conflicts. Most parcels of land are cultivated by tenant farmers as the owners are engaging in other jobs. A few of the older farmers still cultivate but the younger generation is moving out this practice. Active paddy lands with clear ownership rights can deter land grabbing and avoid misuse of subsidies for those who engage in active paddy farming.

Some farmers (13%) cultivate traditional rice varieties of *Oryza sativa* that have nutritional values. These types are mainly grown in small land parcels (0.24-1 acre) for domestic consumption rather than for commercial purposes. The farmers report sightings of numerous faunal species, providing anecdotal evidence for significant biodiversity in paddy lands that grow traditional rice varieties. They

also left a small portion of their land (which they called “Kurulu Paluwa”) as habitat for birds (e.g. little, median and cattle egrets, openbill storks, and grey and purple herons) as well as insect and vertebrate species.

c) Supporting rural livelihoods, equity, and social well-being

Each successive government has prioritized the re-cultivation of paddy lands by providing necessary resources (financial and in-kind), infrastructure and capacity to revive paddy fields. Under Section 22 of the Agrarian Development Act of 2000, land owners, farmers, and beneficiaries are responsible for proper land management. DAD instructed all responsible officials to enforce the government's mandate to re-cultivate fallow paddy lands, with re-cultivation programs being the key solution to restoring abandoned lands (Rathnayake et al. 2022). Restored paddy lands are observed to yield 1,000 - 1,640 kg/acre with a seed input of just 41 kg/acre.



Figure 4. Paddy field preparation for planting rice seedlings. (© Padmini Perera/Manosha Welikala)

Although 15 households are directly supported by the current urban initiative, there are spill-over benefits for neighbouring communities. Restoring paddy lands and reviving the canal network enable proper water drainage and mitigate impacts from floods. The Colombo wetland complex with these paddy lands play a crucial role as a flood retention area and contribute to several significant ecosystem services that make the city liveable. Although rice farming provides direct employment opportunities, these often involve manual physical labour for land preparation, broadcasting, fertilizer application, weed management, harvesting, and transportation (Figure 4). It is often observed that the urban community members seek other modes of income generation that are less laborious and have higher financial returns. 93% of the farmers have diversified livelihoods where they are engaged in other fields of employment such administration, IT, health, construction, and others. Only one out of the 15 farmers in this case study conduct rice cultivation as a full-time livelihood. Labour shortage is an acute challenge in the urban paddy farming sector. Paddy cultivation is strongly tied to cultural and religious activities, especially during rice harvesting. These cultural practices are observed to unite local communities and safeguard social cohesion.

There are also some disbenefits connected to the paddy systems. Leptospirosis and skin diseases are common within paddy farming communities in Colombo (Rajapakse et al. 2020). Leptospirosis, also known as rice-field fever, is a zoonotic disease contracted through contact with rat-infected urine. It is prevalent amongst farmers and the outbreaks coincide with the rice cultivation seasons (Nisansala

et al. 2019). Government authorities conduct awareness sessions on the prevention of leptospirosis and advise seeking medical attention immediately if symptoms arise. Paddy cultivators are regarded as a high-risk occupational group and prophylactic antibiotic therapy is made readily available through the local public health officer. Skin diseases are often manifested because of upstream pollution and strong chemicals used in the past for cultivation.

The DAD has numerous initiatives to incentivise paddy farmers by providing financial/material resources and technical assistance. For a single crop cycle, financial assistance of about USD 50/acre and paddy seed of about 41 kg/acre are provided by the DAD to the farmers. These incentives are to continue as there is an on-going initiative within the Ministry of Agriculture to revive fallow paddy fields to establish self-sufficient farming systems, prevent ecosystem degradation and enhance agricultural livelihoods. Special farmers are selected for seed paddy cultivation so that they learn to develop their own seed paddy varieties if they so wish to. The agriculture extension officers convene meetings prior to the commencement of the two main crop cycles to identify the needs and challenges of the paddy farmers. During these discussions, recent observations in weather and disease prevalence are examined to inform the development of the farming activity plan for the current crop cycle. Certain advanced cropping techniques such as the 'parachute' method are also introduced as part of the technology transfer through extension services. The parachute method is a rice seedling broadcasting technology that was introduced by the Rice Research Institute at Batalagoda, Sri Lanka (Weerakkody et al. 2011). This involves tossing rice seedlings, uprooted from plastic containers containing a soil sphere, in a projectile manner into the paddy field. The seedlings used for broadcasting are uprooted and allowed to grow till sufficient soil weight adheres to the roots, so the seedlings can be dispersed upright. This method is considered as a better alternative for field establishment of paddy as it demands less labour.

d) Building resilience in people, communities, and ecosystems

Restoring the urban paddy fields in Colombo is important for building resilience among people, communities, and ecosystems. The paddy fields reduce the vulnerability of the urban communities to climate variability and its effects, particularly flooding by increasing the water holding capacity of the wetlands (Hettiarachchi et al. 2014a,b). Communities benefit socially and economically from restored paddy cultivation through employment and income. In addition to mitigating floods, the wetland system provides co-benefits such as urban cooling, waste water treatment, fresh water and food provisioning, carbon storage, erosion regulation, pollination and recreation (Rozenberg et al. 2015). By integrating wetland management into broader urban strategies, communities and ecosystems are better equipped to adapt to challenges like climate change, resource scarcity, and pollution (Hettiarachchi et al. 2014a).

e) Responsible and effective governance and institutions

All activities related to paddy land are governed by the Agrarian Development Act which has been enacted and implemented since 1958. The revised Act was introduced in 2000 with the main intention of resolving disputes between tenant-cultivators and landowners. The new Agrarian Development Act No. 47 of 2000 has established effective measures to enable landowners to cultivate agricultural lands according to a predefined set of standards. Furthermore, the Act has introduced a structure for farmer organizations at all levels ensuring the full participation and empowerment of farmers (Alwis and Wanigaratne, 2003).

The National Wetland Policy and Strategy (2006) and the Colombo Wetland Management Strategy (CWMS; 2016) can be considered as the two main regulatory programs to manage wetlands in Colombo. Although not officially launched, many activities are planned following some of the strategies mentioned in the document. In 2018, a moratorium was issued to prevent in-filling, which is still operational today. Some of the related recommendations under the CWMS include enhancing

wetland ecosystem services for cross-sectoral benefits, developing a systematic benefits-based wetland restoration plan, and restoring wetlands as essential elements in climate change mitigation and adaptation programmes. Two key government departments act synergistically to support the functioning of these urban wetlands: the Sri Lanka Land Development Corporation (SLLDC) and the Urban Development Authority (UDA). Cross-sectoral collaboration is vital for effective restoration and for revival of paddy fields. Multiple entities (e.g. Irrigation Department, Ministry of Agriculture, academic institutes, private sector) cooperate to reinstate wetland ecological characteristics, ensure productivity and promote socio-economic welfare.

The National Wetland Steering committee (NWSC) established through a cabinet approval is the main coordinating body (Apex) that governs decisions related to national wetland management. The NWSC consists of key agencies from both conservation and development sectors but faces many challenges in continuing due to insufficient resources and frequent changes in key staff of the constituent state agencies.

Conclusion

Given the importance of paddy fields as multi-functional systems, restoration of paddy can provide numerous benefits related to land and biodiversity conservation, ecosystem service provision, and preservation of socio-cultural harmony. Initiatives to restore paddy lands in the country face numerous challenges, especially due to labour shortages and low economic return. However, increasing resource use efficiency, promoting organic farming, growing traditional varieties with high market value and introducing technological innovations present opportunities to advance paddy cultivation in both urban and rural areas. Identifying and valuing ecosystem services provided by rice paddy land restoration and communicating these for cultivators can assist in incentivising farmers to recommence or continue rice cultivation in urban areas. Combining the restoration of these human-made wetlands with support for the farmers to cultivate rice is crucial for the sustainability of these systems. Further, strengthened institutional coordination is imperative for the implementation of effective wetland management measures that minimize threats to wetlands and promote wise-use of wetlands.

References

- Alwis J, Wanigaratne RD (2003) 3. Agrarian reforms and agricultural productivity: a status review of Sri Lanka's experience. https://www.apo-tokyo.org/wp-content/uploads/2014/07/agr-10-ar_ap.pdf#page=43 (accessed 01 May 2024)
- Hettiarachchi M, Morrison TH, Wickramasinghe D, Mapa R, de Alwis A, McAlpine CA (2014a) The eco-social transformation of urban wetlands: A case study of Colombo, Sri Lanka. *Landscape and Urban Planning* **132**, 55-68.
- Hettiarachchi M, Athukorale K, Wijekoon S, de Alwis A (2014b) Urban wetlands and disaster resilience of Colombo, Sri Lanka. *International Journal of Disaster Resilience in the Built Environment* **5**, 79–89.
- McInnes RJ, Everard M (2017) Rapid assessment of wetland ecosystem services (RAWES): an example from Colombo, Sri Lanka. *Ecosystem Services* **25**, 89-105.
- Nisansala T, Bandara K, Weerasekera M, Gunasekara C, Marasinghe C, et al. (2019) Manifestations and outcomes of leptospirosis during local outbreaks in high endemic districts of Sri Lanka: a retrospective multi-center study. *Asian Pacific Journal of Tropical Medicine* **12**, 442-449.
- Rajapakse S, Weeratunga PN, Balaji K, Ramchandani KC, de Silva US, et al. (2020) Seroprevalence of leptospirosis in an endemic mixed urban and semi-urban setting - a community-based study in the district of Colombo, Sri Lanka. *PLoS Neglected Tropical Diseases* **14**, p.e0008309.

- Rathnayake D, Weerakkody R, Dharmawardhana T, Buhary R (2022) Reversing abandonment: success of re-cultivation efforts in abandoned paddy lands in low country wet zone. Hector Kobbekaduwa Agrarian Research and Training Institute. <https://www.harti.gov.lk/images/download/publication/WP20.pdf> (accessed: 31 October 2024)
- Rozenberg J, Simpson M, Bonzanigo L, Bangalore M, Prasanga L (2015) Wetlands conservation and management: a new model for urban resilience in Colombo. The World Bank, Washington DC.
- Signes (2016) Metro Colombo wetland management strategy. Unpublished report No. MCUDP/PHRD/03 to Sri Lanka Land Reclamation Development Corporation and World Bank. Signes: Paris, France. 107 pp.
- Weerakkody PR, Kumara SK, Wickramasinghe WD (2011) Adoption of parachute technology by the farmers in Anuradhapura District. Hector Kobbekaduwa Agrarian Research and Training Institute. https://www.harti.gov.lk/images/download/reasearch_report/140.pdf (accessed: 01 May 2024).
- Weerakoon P, Thayaparan M, Weerakoan TP (2023) Challenges in circular urban water management in construction industry of Sri Lanka. In: FARU Proceedings 2023, Colombo, Sri Lanka: University of Moratuwa, pp.163–171. doi:10.31705/FARU.2023.18 (accessed: 25 October 2024).

Case 4. Accelerated natural regeneration of mangroves in Anawilundawa Wetland Sanctuary, Sri Lanka and its contribution to sustainable shrimp aquaculture

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Site details

Item	Details
Site name	Anawilundawa Wetland Sanctuary (formerly “Annaiwilundawa Tanks Sanctuary”)
Contracting Party/Country	Sri Lanka
GIS Coordinates	7°42′ N, 79°49′ E
Site ID	1078
RIS last updated	3 August 2001
RIS source	https://rsis Ramsar.org/RISapp/files/RISrep/LK1078RIS.pdf
Surface area of case site (ha)	1397 ha
Wetland type	Mangroves; Aquaculture ponds
Agricultural system type	Aquaculture extensive (ponds)

Main key message

Between 1980 and 2000, coastal aquaculture in Sri Lanka led to the destruction of mangrove forests, with 90% of farms subsequently affected by disease and contamination. Successful restoration in Anawilundawa Wetland Sanctuary was achieved with a combination of scientific research, restoration of degraded mangroves, promoting sustainable shrimp farming practices, support and training for surrounding communities, and promotion of collaboration among government and non-government stakeholders.

The challenge presented by shrimp production in relation to coastal wetlands in Sri Lanka

The ecological character of wetlands encompasses their unique hydrology, vegetation, soil, and wildlife, which together define their functionality and biodiversity. The conversion of wetlands for agriculture or aquaculture often compromises these characteristics. Sri Lanka, with a coastline of 1,785 km, has traditionally practiced artisanal fisheries in lagoons and estuaries, with Black Tiger Shrimp (*Penaeus monodon*) as a key species harvested. However, with the introduction of intensive shrimp farming technology in the 1980s, the shrimp aquaculture industry rapidly expanded specifically in the coastal areas of the Northwestern part of Sri Lanka (Bournazel et al., 2015). Approximately 38% of the country's total mangrove loss is attributed to the conversion of mangroves into aquaculture ponds (Bandara et al., 2022). This expansion, although profitable, led to environmental challenges such as mangrove destruction, water pollution, and disease outbreaks like White Spot Syndrome Virus (WSSV), Yellow Head Viral Disease (YHD) and introduction of exotic shrimp such as *Litopenaeus vannamei*.

While the Sri Lankan government and international organizations have introduced sustainable shrimp farming practices, such as better management practices (BMPs) and environmental safeguards, the shrimp industry still requires careful management, particularly in restoring degraded and abandoned coastal areas (Jayakody et al., 2012). Mangroves, which thrive alongside shrimp farms, play a crucial role in coastal ecosystems by providing essential ecosystem services and functions. They serve as breeding and nursery grounds for finfish and shellfish, which are vital for supporting Sri Lanka's socio-economic sustainability. There are 82 coastal lagoons and estuaries that support a rich biodiversity, including 21 true mangrove species. However, over the past 30 years, mangroves have declined, leaving only 19,874 hectares (Global Mangrove Watch 2024). In response, the Sri Lankan government has prioritized mangrove conservation and restoration, integrating them into climate change mitigation strategies under the Nationally Determined Contribution and into adaptation strategies. Two pilot restoration sites, Pubudugama and Anawilundawa, were initiated by the Department of Forest Conservation and the Department of Wildlife Conservation, respectively.

Anawilundawa, Sri Lanka's second Wetland of International Importance, includes 45 hectares of abandoned shrimp farms adjacent to healthy mangroves. Since 2019, this area has been restored using "accelerated/assisted natural regeneration" techniques. The project Accelerated Natural Regeneration of Mangroves (ANRM), driven by government, private sector, academia, and local communities, aims to restore ecosystem services while facilitating sustainable shrimp farming in the periphery of the sanctuary. Results so far indicate successful rewilding and growing community trust in the restoration process and demonstrate how local communities, the private sector, academia, civil society, youth groups, non-governmental organizations, and international institutions. can work in collaboration .

Actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

Sri Lanka introduced measures to make shrimp farming more sustainable, such as zonation of shrimp farming areas, environmental impact assessment for land allocation prior to development, post larval screening for diseases and better management practices (BMPs) at various stages in shrimp aquaculture development (FAO/NACA/UNEP/WB/WWF 2006). The National Aquaculture Development Authority was established to monitor the compliance. This initiative works very closely with the shrimp farmers in the vicinity, developing capacity and awareness regarding the role played by healthy mangroves and also revegetating the active farms to bring environmental services.

b) Protecting wetlands and mitigating pressure/impact on wetlands

The objective of the ANRM project was to restore the degraded mangrove ecosystems within the Anawilundawa Wetlands as per the National Guidelines for the Restoration of Mangrove Ecosystems (Ministry of Environment 2021). The project was launched as part of mangrove rewilding attempts of the Department of Wildlife Conservation. The department partnered with Wayamba University of Sri Lanka for technical expertise, with two NGOs (the Wildlife and Nature Protection Society and Biodiversity Sri Lanka) to create links with the private sector, and with the Young Zoologist Association and the Blue Resources Trust (another NGO) to support the scientific investigations. The Hydrography Unit of the Sri Lanka Navy (SLN) conducted topographic mapping and bathymetric surveys, and developed a contour map. These efforts were essential to facilitate controlled water conveyance from the Dutch canal (a 14.5 km canal connecting Puttalam to Colombo) into the mangrove habitat in a methodical and regulated manner. The canals excavated for irrigating the replanted plots were consistent with the main canals and sub canals, and their dimensions differed from plot to plot (Figure 1). The total investment for the canal development project amounted to over 10 million Sri Lankan Rupees so far.



Figure 1. Newly excavated straight and contoured channels to restore hydrology and condition the soil. Active shrimp farms are in the other side of the sanctuary. (© WNPS)

In addition to infrastructure development, on-going biodiversity surveys focusing on birds, butterflies, gastropods, and bivalves have played a crucial role in preserving wetland biodiversity. An initial baseline survey was conducted to identify key ecological characteristics, informing subsequent actions aimed at preserving and enhancing the unique ecological features of the wetlands. This proactive approach has been instrumental in maintaining the distinct ecological profile of the wetland area. Additionally, data were collected on associate flora (especially salt marsh species) in order to ensure minimal damage to other blue carbon ecosystems.

Mangrove restoration was conducted using only the 13 true mangrove species locally available in Anawilundawa wetland area (Table 1). The approach was aimed at preserving genetic integrity and preventing gene mixing within the restored mangrove ecosystem. Utilizing only the native mangrove species found naturally in the area ensured ecological authenticity and maintained the unique genetic diversity of the local mangrove population. A fruiting calendar is underway to ensure that local fruiting seasons are known with the local knowledge and information from local fishermen when they venture into the mangroves for fishing.

Table 1. True mangrove species occurring in the Anawilundawa Wetland Sanctuary.

Family	Genus	species
<i>Primulaceae</i>	<i>Aegiceras</i>	<i>corniculatum</i>
<i>Acanthaceae</i>	<i>Avicennia</i>	<i>marina</i>
<i>Acanthaceae</i>	<i>Avicennia</i>	<i>officinalis</i>
<i>Rhizophoraceae</i>	<i>Bruguiera</i>	<i>cylindrica</i>
<i>Rhizophoraceae</i>	<i>Bruguiera</i>	<i>gymnorhiza</i>
<i>Euphorbiaceae</i>	<i>Excoecaria</i>	<i>agallocha</i>
<i>Malvaceae</i>	<i>Heritiera</i>	<i>littoralis</i>
<i>Combretaceae</i>	<i>Lumnitzera</i>	<i>racemosa</i>
<i>Arecaceae</i>	<i>Nypa</i>	<i>fruticans</i>
<i>Rhizophoraceae</i>	<i>Rhizophora</i>	<i>apiculata</i>
<i>Rhizophoraceae</i>	<i>Rhizophora</i>	<i>mucronata</i>
<i>Rubiaceae</i>	<i>Scyphiphora</i>	<i>hydrophyllacea</i>
<i>Meliaceae</i>	<i>Xylocarpus</i>	<i>granatum</i>

Before field planting, the seedlings were grown in nurseries nearby to acclimatise them for the environmental conditions, thereby providing an alternative livelihood to communities. The water utilised for irrigating the mangrove nurseries was sourced from the Dutch Canal and applied to the nursery bags twice per day until saturation was achieved. Systematic contour mapping was conducted, again in partnership with the SLN, followed with systematic breaking of existing dykes and construction of canals to reirrigate the abandoned ponds. Following the transfer of mangrove plants to the canal systems, no further irrigation was provided, as the canals naturally receive water from high tides which recedes during low tides, facilitating efficient water usage.

The mangrove nurseries (Figure 2, left) were not supplied with fertilisers; instead, they utilised sand and mud collected from the bottom of the Dutch Canal carefully, minimising the disruption to the surrounding environment. In response to a pest infestation in their initial nursery, a homemade pesticide was applied to the leaves, consisting of a blend of Neem leaves and onion skins. This pesticide -was sprayed daily for a week, although its effectiveness was not absolute. Despite this, the impact of the pest attack on plant survivability was minimal, with a nursery survival rate of 95%. No external energy sources were utilised in the operation of these nurseries. Resource efficiency was achieved by in situ maintenance of nurseries, eliminating transport costs, travel of workers and also depending on natural flow of water by careful structuring of canals along natural gradients. Also, throughout the project unmechanised catamarans were used to transport seedlings, thereby providing alternative income to communities as well as ensuring less carbon footprint in transportation. Field plantation endeavours achieved an 80% survival rate for mangrove plants, indicative of successful implementation (Figure 2, right).

c) Supporting rural livelihoods, equity, and social well-being

The ANRM project has directly benefitted 10 families residing in the nearby Muthupanthiya village. However, the positive impacts extend to the broader community encompassing Anawilundawa, Muthupanthiya, and Naguleliya villages. The project engaged ten males and two females from neighbouring households who actively supported the regeneration efforts and were compensated based on assigned tasks. These individuals collectively contributed approximately 200 hours per year to project-related activities. The project also supported employment by hiring three research officers, one field engineer, and one accountant on a full-time basis. Community involvement was fostered

through specific tasks such as seed collection, planting, and nursery preparation, enabling residents to participate and earn income from project-related activities (Figure 3). This inclusive approach not only facilitated ecological restoration but also provided economic opportunities within the surrounding communities. While promoting sustainable livelihoods among wetland communities, they were made aware about the need to improve the natural environment, especially the mangroves around active shrimp farms, through dialogues and also through partnerships where local communities were involved with day-to-day running of the site. At present the local communities provide boat services to researchers and also accommodation and food. Gradually their skills to operate households as “homestay” are improving. In addition to this, local communities are now connected with the private sector enabling their marketing of products.



Figure 2. Left: mangrove nurseries (copyright HNTM Kumarsiri). Right: planted vs naturally settled. *Avicennia marina* has naturally settled and is growing faster compared to planted *Rhizophora mucronata*. (© Sevvandi Jayakody)

d) Building resilience in people, communities, and ecosystems

Initially, there was a misunderstanding about the project within the surrounding community. This was mainly due to lack of awareness on the role that mangroves play in shrimp farming. Since farmers used to complete removal of mangroves when constructing shrimp ponds, they view mangroves as plants that cannot exist with shrimp ponds. Educational outreach was conducted to highlight the advantages and economic opportunities associated with mangrove ecosystems, such as enhanced fishing, shrimp harvesting, and opportunities for bird watching, all of which contribute to sustainable income generation. This fostered a closer relationship with village communities and developed resilience in people.

Mangrove restoration plays a critical role in mitigating the impacts of floods and droughts. By restoring and conserving mangrove ecosystems, we can effectively reduce the risk of flooding and drought events. Mangroves and mud flats serve as natural barriers, preventing the intrusion of saline water into nearby paddy fields, crucial for maintaining agricultural productivity. The shrimp farmers were educated on the importance of mangrove conservation, illustrating how preserving these areas can directly benefit their activities. This integrated approach aimed at fostering greater awareness and appreciation for mangrove conservation among local communities.



Figure 3. Participation of private sector for restoration related data collection.
(© Hayleys Advantis)

A comprehensive technical training session was organised for the surrounding community, covering diverse fields such as dairy production, poultry farming, business management, entrepreneurship, home garden farming, ornamental fish and plants, and techniques for managing bycatch in the fishery industry. The training session engaged a group of 20 participants and served as a platform to equip community members with practical skills and knowledge necessary for diversifying livelihoods and fostering local entrepreneurship. As a result of the training, three individuals from the participant group will receive funding for seeds to establish their own businesses in the future. This initiative aims to support entrepreneurial endeavours within the community, promoting economic growth and sustainability among the trained individuals.

e) Responsible and effective governance and institutions

Top-down and bottom-up approach to the governance and institutional arrangements around Anawilundawa can be distinguished. From a top-down perspective, Sri Lanka has established comprehensive policies, strategies, and institutional mechanisms for the conservation and restoration of mangroves. These policies emphasize climate change adaptation, environmental conservation, gender equality, partnerships, and access to clean air, water, and soil. The key strategies that have been implemented include:

- the National Policy on Conservation and Sustainable Utilisation of Mangrove Ecosystems in Sri Lanka (2020), which provides a framework for protecting and wise use of mangroves as vital ecosystems;
- the National Strategic Action Plan for Conservation and Sustainable Utilisation of Mangrove Ecosystems (2022-2026); and
- the National Guideline for the Restoration of Mangrove Ecosystems (2021).

Understanding that restoration of degraded mangrove ecosystems requires the support of multiple agencies, a National Mangrove Expert Committee was established in 2015. Formed under the Ministry of Environment, this multi-stakeholder committee comprises representatives from ministries, departments, academia, NGOs, and CBOs. The committee focuses on identifying gaps in policy and administration and raising awareness by engaging with stakeholders at the ground level. It also advises government agencies on emerging issues related to mangrove conservation. In 2019 the Task Force for Conservation and Restoration of Blue Carbon Ecosystems was established to promote scientific research and action on mangrove restoration.

The bottom-up approach involved the Department of Wildlife Conservation developing MoUs to partner with NGOs. At present, the Wildlife and Nature Protection Society acts as the lead science NGO. Biodiversity Sri Lanka is also heavily involved. Academia conducts scientific investigations and

regular monitoring. International collaborations and private sector donors fund project activities including community welfare, education and monitoring. Ground level staff is in constant dialogue with communities on issues related to fishing and aquaculture, sharing information and providing scientific insights. Soon a weather station will be established to support shrimp farmers. On-site facilities, including a visitor centre, support engagement with children and youth to learn and become local champions to manage their environment whilst benefitting from mangrove resources.

Conclusion

This initiative restored mangrove ecosystems and enhanced their services and functions, particularly as breeding and feeding grounds for finfish and shellfish. As a result, the socio-economic conditions of surrounding communities have improved through sustainable harvesting practices. Efforts to restore mangrove ecosystems need to be guided by scientific principles if they are to be effective and sustainable. Restoration efforts of the degraded Anavilundawa Wetland Sanctuary aimed at the sustainable coexistence of biodiversity, human communities and their livelihoods. Contour mapping before canal excavations provided critical insights into the hydrology of the area, facilitating more efficient water management. Baseline surveys identified key ecological features, preserving the wetland's unique profile, and guiding targeted conservation efforts. By employing natural instead of synthetic pesticides, the project improved pest management practices while promoting environmental sustainability. The robust partnerships and strategic investments to leverage scientific insights, community engagement, and innovative practices resulted in enduring environmental stewardship. The case highlights the significance of evidence-based conservation and restoration practices in achieving long-term ecological resilience. This has been recognized globally, with Sri Lanka being named a 2024 UN World Restoration Flagship for its exemplary efforts in restoring and rejuvenating mangrove ecosystems.

References

- Bandara HMSM, Upananda WLPB, De Silva CS (2022) Impact of shrimp farming on degradation of diversity, soil, and water quality of mangrove ecosystem in Anawilundawa Ramsar wetland sanctuary. Available at https://ours.ou.ac.lk/wp-content/uploads/2022/12/ID-13_IMPACT-OF-SHRIMP-FARMING-ON-DEGRADATION-OF-DIVERSITY.pdf (Accessed on 02nd May 2024)
- Bournazel J, Kumara MP, Jayatissa, LP, Viergever K, Morel V, Huxham M (2015) The impacts of shrimp farming on land-use and carbon storage around Puttalam lagoon, Sri Lanka. *Ocean & Coastal Management* **113**, 18-28.
- FAO/NACA/UNEP/WB/WWF (2006) International principles for responsible shrimp farming. The Government Council of the Network of Aquaculture Centers in Asia-Pacific, Bangkok. p. 20.
- Global Mangrove Watch (2024) Sri Lanka. Available at <https://www.globalmangrovetwatch.org/country/LKA> (accessed on 16th October 2024)
- Jayakody S, Jayasinghe JMPK, Wijesundara AH (2012) Active versus passive restoration of mangroves: developing models for sustainable rejuvenation of mangrove ecosystems used for shrimp farming in North-western Province of Sri Lanka. IUCN Special edition on Mangroves of Asia, IUCN, Bangkok.
- Ministry of Environment (2021) National Guidelines for the Restoration of Mangrove Ecosystems, Sri Lanka. Available at: <https://www.env.gov.lk/web/index.php/en/publications/biodiversity>
- Convention on Wetlands (2024) Information Sheet on Ramsar Wetlands. Available at <https://rsis Ramsar.org/RISapp/files/RISrep/LK1078RIS.pdf> (accessed on 19th April 2024)

Case 5. Sustaining agriculture-wetlands interactions in the management of Vembanad-Kol wetlands

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Site details

Item	Details
Site name	Vembanad-Kol Wetland
Contracting Party/Country	India
GIS Coordinates	76°01' and 76° 34' E longitudes, 9°15' to 10°36' N latitudes
Site ID	1214
RIS last updated	19/08/02
RIS source	https://rsis Ramsar.org/ris/1214
Surface area of case site (ha)	Vembanad-Kol Wetland: 132,300 ha; comprising of three ecological zones: Vembanad Estuary: 42,900 ha; Kol wetlands: 13,632 ha; and Kuttanad: 75,768 ha
Wetland type	Estuaries, tidal flats, saltmarshes, lagoons; Rivers, streams, floodplains
Agricultural system type	Rainfed extensive; Aquaculture extensive

Main key message

The Vembanad-Kol Wetland (VKW), comprising the Vembanad Estuary flanked by the Kol agricultural floodplains and the farming systems of Kuttanad, serves as the food bowl of Kerala. The below sea level agriculture practised in VKW provides direct and indirect livelihoods to 150,000-200,000 persons who reside within the system as well as in its vicinity. The wetland farming systems in the region have evolved since the 18th century to address the food security needs of local residents in an area where land is scarce. If managed properly, these farming systems can coexist with the wetlands without compromising their essential regulating ecosystem functions and services. However, due to the impacts of climate change and developmental pressures, these farming systems have started to deteriorate. This decline can be mitigated through improved land and water management, along with appropriate incentives for farmers to prevent changes in land use.



Figure 1. Location of Vembanad-Kol, Wetland of International Importance. (© WISA & CWRDM, 2024)

The challenge presented by floodplain agriculture in relation to Vembanad-Kol Wetland

Major portions of Kuttanad and Kol lands are below sea level and flood for prolonged periods after the monsoon season. Brackish marshes around the city of Kochi have traditionally been used for rice-shrimp aquaculture, locally known as Pokkali. The rice paddies of Kuttanad and Kol lands form an integral part of the Vembanad-Kol Wetland (VKW) in Kerala state on the southwest coast of India (Figure 1), and their sustainable management is an important precondition for achieving the Convention on Wetlands goal of 'wise use'. The Integrated Management Plan for VKW aims to directly benefit the dependent communities of the Wetland by incorporating new guidelines from the National Plan for Conservation of Aquatic Ecosystems (WISA and CWRDM, 2024).

Kol lands (paddy rice cultivation)

The Kol lands (northern part of VKW) are floodplains of Rivers Keecheri, Puzhakkal and Karuvannur, reclaimed for agriculture. The floodplains are freshwater-dominated systems located 0.5-1 m below sea level and have been used for rice and fish farming since the 18th century (Figure 2). Around 50,000 farmers organised in about 130 cooperative societies (*Padasekharam* in the Malayalam language) own these wetlands. Paddy cultivation is critical for sustaining these wetlands and involves coordinated dewatering by pumping from low-lying fields to channels around the embankments using a traditional practice known as *Kootaima reeti*. Some societies practice crop rotation with aquaculture from June to October followed by rice cultivation. The productivity of agriculture is maintained by recycling of crop residues. The wetland continues to be an important flood buffer and a biodiversity hotspot, with 167 bird species of which 81 are wetland-dependent and 53 are migratory (WISA and CWRDM, 2024).



Figure 2. Integrated rice-shrimp cultivation in Kol lands. (© Wetlands International South Asia)

Vembanad estuary (integrated deepwater rice-prawn farming)

In the Vembanad estuary (central part of VKW), integrated rice and prawn farming (a system called *Pokkali*) has been practiced since over 3,000 years using a rice variety that grows throughout the monsoon season above the water surface upto a height of 130-140 cm and withstands salinities upto 8 ppt. About 80-100 kg/ha of Pokkali rice is sown immediately after the onset of the southwest monsoon in June. The crop takes 90-100 days for maturing and the mature pinnacles are harvested end of October or early November. The stalks are left to decay in the field. From mid November, salinity increases and prawn and fish farming takes over. The lower salinity relative to the sea triggers the movement of prawn post-larvae and fish juveniles, guided by sluice gates to the Pokkali fields, where they feed on the decaying rice stalks. Trapping/harvesting starts from mid January, every 3-4 days before and after full moon and new moon, and continues until late March when the fields are drained and prepared for the next paddy cycle. Prawns form about 80% of the catch, the rest is fish.

Pokkali farming is completely organic. It continues to be profitable even after the increasing cost of inputs and labour. In a typical 1 ha farm, 1500 kg of rice and 420-900 kg of prawns can be harvested with a net profit of INR 47,110 per cycle compared to INR 10,100 from rice monoculture (Francis et al., 1999). In 2008, Pokkali rice was accorded Geographical Indication status¹. However, since 2009 the practice has been stressed due to incidence of diseases, reduced availability of labour and high wages. The land is increasingly converted to intensive prawn farming or coconut cultivation. With a gradual decline in natural recruitment, farmers have resorted to stocking the farms with purchased post-larvae resulting in higher production of 5-7.5 tonnes/ha. With stocking, the average farm income has been reported to be around 390,000 INR/ha.

Kuttanad (below sea-level rice cultivation)

The Kuttanad rice fields (southern part of VKW) are floodplain formations of Rivers Achencoil, Pamba, Manimala, Meenachil and Muvattupuzha. The entire Kuttanad is at or below sea level and remains waterlogged and marshy for large parts of the year. Below sea-level agriculture in Kuttanad is recognised by FAO as a Globally Important Agricultural Heritage System (see <https://www.fao.org/giahs/giahsaroundtheworld/india-kuttanad-farming-system/en>). Large parts of Kuttanad comprise of land reclaimed from Vembanad estuary and the floodplain marshes of the rivers, and exist in clusters called polders bound by outer embankments (locally called *Padashekharams*). Over 1200 polders, varying in size from 1 to over 900 ha, cover an area of 594 km². Farming is collectivized and managed by the Padashekharam management committees, which schedule dewatering, irrigation, and other farm activities in each polder (Figure 3).

During the *Punja* season, rice is sown after the southwest monsoon and harvested before tidal intrusion of seawater during summer. Rice cultivation is based on meticulous manoeuvring of water levels. In March-April, ploughing and application of lime to reduce soil acidity are followed by letting in canal water to inundate the fields throughout the southwest monsoon period. This suppresses capillary rise of salts from below the soil. In August-September when water levels decrease, outer bunds encircling the fields are repaired. As the south-west monsoon subsides, a second ploughing in waist-deep water is done. Then dewatering is done, followed by repairs of inner bunds and weeding prior to sowing. Seeds are packed in screw-pine bags and soaked to induce sprouting. The sprouted seeds are transplanted and fertilizers are applied. After 25-30 days, the overcrowded portions are thinned out. Harvesting is done by cutting the ear heads, which are then thrashed, the paddy separated and transported in storage barns.

Hydrological interventions contribute to salinity control and flood management. Thottapally spillway, constructed in 1955, diverts the monsoon inflows of the rivers. The Thanneermukom Barrage across the Vembanad estuary prevents salinity intrusion from the Kochi mouth.

Despite the various measures taken, agrarian distress has persisted in the region since the mid-2000s. Traditional paddy varieties matured within 100 days with an average yield of around 1,200 kg/ha. The introduction of high yielding rice varieties with a longer maturity period (120–130 days) led to changes in cropping schedules, forcing closure of the Thanneermukom Barrage for longer periods. This gives rise to conflicts with the fisher communities who report interference in migratory pathways, loss of nursery grounds and decline in catch. The average fish catch per group of 6 fishers has now reduced to 7-8 kg/d (for 200 days per annum) as against 20 kg reported in 2000 (WISA and CWRDM, 2024).

¹ A geographical indication (GI) is a name/sign corresponding to a specific geographical location or origin. A GI may act as a certification for traditional production methods or product qualities related to its geographical origin.



Figure 3. Below sea level farming in Kuttanad Region. (© Wetlands International South Asia)

Pest and crop diseases led to increased use of chemical pesticides and fungicides. Not all the reclaimed polders could be used for agriculture, as waterlogging continued in the blocks adjoining the estuary. High costs of labour and maintenance (embankments, pumps, allied infrastructure) has affected profitability (Ranjit and Kurup, 2001). The paddy cultivators are relinquishing rice cultivation in favour of less labour intensive activities such as coconut farming and aquaculture. A sizeable area of the paddy fields is left fallow during most of the year. Remote sensing images by the Kerala State Land Use Board show that the area under paddy reduced from 609 to 376 km² during 1963-2003, coupled with an increase in areas left fallow and converted for non-agricultural uses. Kuttanad was identified as a farm- distressed region by the Ministry of Agriculture (Government of India) in 2006.

The canals are choked by invasive plants (mainly water hyacinth) which aggravates waterlogging. Roads constructed across the floodplains obstruct flows. Kuttanad witnessed large scale devastation in 2018, when heavy rainfall and the breaching of polder walls drowned over 50,000 houses (KSPB, 2019). Since then, regular flooding has forced people to migrate out of the region.

Actions or opportunities to make the system more sustainable

a) Options for increasing resource use efficiency

Farming in the Kuttanad and Kol region requires maintenance of hydrological regimes, aligned with the agricultural requirements, while ensuring that key ecosystem processes and biodiversity values are not adversely affected. This is done by aligning crop calendars with natural hydrology and regulating water. Key to achieving those regimes is Thaneermukkom Barrage, of which the sluice gates have been motorized. To enhance hydrological connectivity within VKW and attenuate the risk of flooding in some peripheral regions, declogging works and removal of encroachments across rivers, canals and waterways are under implementation.

A crop calendar harmonized with the ecology of the Vembanad estuary is under development. Traditional methods of dewatering are being replaced by modern systems. Financial assistance for solar pumps is envisaged to reduce the dependency on conventional energy sources. Large parts of VKW have been declared as a Special Agriculture Zone (SAZ) for rice to ensure greater coordination of programmes and SAZ funding. Kuttanad Package Phase II emphasizes operationalisation of a SAZ plan for Kuttanad, the preparation of a crop calendar for paddy, modernisation of existing dewatering systems, integrated farming systems, integrated pest management and other measures.

b) Protecting wetlands and mitigating pressure/impact on wetlands

The VKW is protected under the provisions of the Wetlands (Conservation and Management) Rules, 2017 and the Coastal Zone Regulation under the Environment Protection Act, 1986. The Vembanad backwaters (the estuary region), in consultation with local communities, has been declared as a Critical Vulnerable Coastal Area (CVCA) to promote conservation and sustainable use of coastal resources and habitats. The Kerala Conservation of Paddy Land and Wetland Act of 2008 prohibits the conversion of paddy land and wetlands for other uses. The integrated management plan for VKW provides a blueprint for protecting wetlands and managing risks of adverse change.

c) Supporting rural livelihoods, equity, and social well-being

The Kuttanad Rehabilitation Package, amounting to INR 18,400 million, was launched in 2010. The current Kuttanad Package Phase II aims to revamp agriculture in the wetland and includes reorganizing crop production, improved management of Thanneermukom Barrage, reduction in freshwater invasives, improvement of fisheries, improvement of drinking water and sanitation facilities, and livelihood improvement. Rejuvenation of silted panchayat ponds is suggested as a measure to serve domestic water needs and enhance the flood buffering capacity of the landscape.

Efforts are underway to revive *Pokkali* farming in Thrissur, Ernakulam, and Alappuzha districts through incentive programmes for *Pokkali* farmers, improving cropping practices and establishing forward and backward market linkages. The *Pokkali Samrakshana Samithi* has leased out *Pokkali* lands through 'Pokkali bonds' for cultivation to reach out to farmers who abandoned *Pokkali* farming or switched to prawn monoculture because of poor market price of *Pokkali* rice. This will help them cover labour costs and farm mechanization needs. *Pokkali* harvest festivals are being organised annually since 2022.

d) Building resilience in people, communities, and ecosystems

Soil salinity and soil acidity issues are reported from some parts of Kuttanad. Maintenance of ambient salinity levels are critical for cultivation of *Pokkali* rice. Installation of sensors and mapping of soil salinity will guide mitigation measures. Convergence with marketing and central and state government support for crop insurance schemes is envisaged to alleviate farming distress.

Addressing water and land management issues, and reduction of pollution from farmlands can be achieved through collation and publication of a package of wetland-friendly practices along with outreach workshops. Incentives for adopting good agricultural practices are proposed, such as reducing artificial fertilizers and pesticides, adopting organic farming, and cultivation of climate resilient paddy varieties. Effective support for farmers and follow-up action would be initiated in coordination with the capacity development institutions and responsible enforcement agencies.

In Kerala, a farm plan-based development approach was introduced in the 2022-2023 period. This initiative promotes the adoption of scientifically selected farming components and appropriate agro-management practices tailored to specific Agro Ecological Units (AEUs) to minimize the risks associated with crop loss. The program is implemented with the support of Krishi Bhavans (Department of Agriculture), focusing on scientific planning and knowledge. It targets production-based planning, development of production organizations, technology support, and the integration of supply and value chains.

e) Responsible and effective governance and institutions

The Kerala State Government has constituted the State Wetlands Authority (SWAK) as the overall organization responsible for policy-making, programming and enforcement of extant regulations. The ambit of SWAK includes the management of VKW. The management plan envisages a dedicated VKW Management Unit under the aegis of SWAK and administrative control of the Environment Department, Government of Kerala. The unit would serve as a site manager and be responsible for

coordinating implementation of the management plan, enforcing regulation, raising resources for site management, networking and collaboration, capacity building, and communication and outreach. Management design and implementation would be in consultation with Local-self Governments. An online Wetlands Inventory, Assessment and Monitoring System has been implemented to provide updated information on status and trends in various wetland features. The administrative challenges in Kuttanad's farming sector are being addressed through the Kuttanad Development Coordination Council established under the chairmanship of the Chief Minister. The council aims to promote the overall development of Kuttanad by coordinating the implementation of projects across various departments. The SWAK is also coordinating the embedding of wetlands management in plans and programmes for agriculture, urban development, tourism, disaster management and other relevant sectors.

Conclusion

Agriculture forms a part of the ecological character of the VKW, and thereby, efforts to regulate and manage the Wetland of International Importance have also emphasised sustaining these farming systems within the ecological limits. However, these efforts have been under stress from land use changes in the catchments, increasing frequency of extreme events, increased pollution loads, spread of invasive species and others. While the governments have put in place a regulatory framework and an integrated management plan, the wise use of wetlands is contingent upon systematic implementation of the management plan, and the ability of existing institutions and governance arrangements to embed wetlands management in sector plans, programmes and investments.

References

- Francis G, Focken U, Becker K (1999) A traditional rice-prawn rotation culture system from Kerala State, India. Deutscher Tropentag 1999 in Berlin Session: Sustainable Technology Development in Animal Agriculture 1-7.
- KSPB (2019) A Special Package for Post-Flood Kuttanad. Kerala State Planning Board. Available at: https://spb.kerala.gov.in/sites/default/files/2020-09/Kutanad_Large2.pdf
- Ranjeet K, Kurup BM (2001) Economic analysis of polder based freshwater prawn farming systems in Kuttanad, India. *International Journal of Fisheries and Aquaculture* **5**, 110-121.
- WISA and CWRDM (2024) Vemabanad-Kol Wetlands - An Integrated Management Planning Framework for Conservation and Wise Use. Technical Report submitted to the State Wetland Authority Kerala (SWAK). Wetlands International South Asia, New Delhi, India.

Case 6. Supporting rice farmers to protect the endangered Eastern Sarus Crane (*Grus antigone sharpii*) in Northeast Thailand

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Site details

Item	Details
Site name	Huai Chorakhemak Non-hunting Area, located in Muang district, Buriram province in northeast Thailand
Contracting Party/Country	Thailand
GIS Coordinates	103°02'02.5"E ; 14°54'02.7"N
Site ID	N/A
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	6.2 km ² surrounded by paddy fields
Wetland type	Water storage bodies (reservoirs); Agricultural wetlands (rice paddy)
Agricultural system type	Rainfed intensive; Irrigated

Main key message

Paddy rice fields surrounding a non-hunting wetland area in Buriram Province in Northeast Thailand are habitats for the endangered Eastern Sarus Crane (*Grus antigone sharpii*). Financial mechanisms to encourage organic farming practices and conservation of wetland species include rebranding the rice as "Sarus rice" to obtain a higher market price, compensation for damage from crane nesting and foraging, and ecotourism opportunities to increase farmers' income.

The challenge presented by rice production in relation to Eastern Sarus Crane conservation

The Eastern Sarus Crane (*Grus antigone sharpii*) was widespread across Southeast Asia in the past, but its population and historic range severely declined due to hunting, egg collection and declining quality of wetlands habitats (Harris and Miranda 2013). The Eastern Sarus Crane had been listed as extinct in the wild in Thailand because of its habitat loss and degradation. Crane species more generally, and many other waterbirds, depend on agricultural lands around the world (Austin et al. 2018).

Huai Chorakhemak is a non-hunting area surrounded by paddy fields in Buriram province (Figure 1). This non-hunting area encompasses a reservoir and the immediate protected wetlands around it. This area is specifically set aside for wildlife conservation, preventing hunting and other activities that could

harm the ecosystem. The reservoir serves as a critical water storage and management facility, aiding in flood control, irrigation, and providing water for agricultural activities in the region. The primary agricultural activity around the Huai Chorakhemak Reservoir is rice farming. The reservoir plays a crucial role in providing irrigation water, especially during the dry season. Farmers depend on the controlled release of water from the reservoir to maintain their paddy fields. This protected area is known for its efforts in wildlife conservation, particularly for the Eastern Sarus Crane.

The Zoological Park Organization (ZPO) and the Department of National Parks, Wildlife and Plant Conservation have jointly implemented the Eastern Sarus Crane Reintroduction Project since 2011 in the non-hunting area. The Eastern Sarus Crane uses habitats both in the non-hunting area and privately owned paddy fields. The impact on household income was listed as the most serious concern.



Figure 1. Sarus crane nesting in the buffer zone of Huai Chorakhemak Non-hunting Area. (©Preecha Norsingha)

Actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

To minimize conflicts between habitats and agriculture, the project promotes organic rice farming as a sustainable alternative to conventional methods. Organic rice farming was introduced in 2000 by the Sawai So village head in Sake Prong subdistrict and has since expanded. This practice focuses on reducing chemical inputs and enhancing soil health. Participating farmers use cattle manure and decomposed rice straw to enrich paddy soil with organic matter, substituting chemical fertilizers. Herbicides are replaced by manual weeding, further reducing environmental impact. Rice paddies affected by bird nesting and feeding activities are reimbursed by the Bird Conservation Society of Thailand and the Zoological Park Organization (ZPO). This support has encouraged the adoption of chemical-free rice farming practices, resulting in the revival of the local ecosystem (see <https://www.thegef.org/news/cooperation-coexistence-thailand>).

Organic practices have also demonstrated long-term cost efficiency. While yields may initially be lower, soil quality improves over time, leading to increased productivity and profitability after three to five years.

b) Protecting wetlands and mitigating pressure/impact on wetlands

The project integrates wetland and bird conservation through a recovery plan and reintroduction programme for the Eastern Sarus Crane, led by the Zoological Park Organization (ZPO) and other government agencies since 2010. Huai Chorakhemak and its buffer zones, covering over 4,500 km²,

were identified as suitable reintroduction sites due to their ecological characteristics and community support. Farmers in the area receive compensation for crop damage caused by cranes, fostering coexistence between agriculture and conservation.

To further mitigate pressures on wetlands, the project employs NCAPS (Network Centric Anti-Poaching System) cameras to monitor Sarus Crane nests, ensuring protection during hatching periods. These efforts have resulted in over 70% survival rates for reintroduced cranes and the successful adaptation of juvenile populations.

c) Supporting rural livelihoods, equity, and social well-being

The organic rice farming initiative successfully harmonizes wetland conservation and agriculture by re-branding to “Sarus rice” symbolizing the integration of organic rice farming practices and bird conservation efforts (Figure 2). This iconic product of Buriram Province fetches a premium price of THB 80 (USD 2.4) per kg, compared to THB 35–40 (USD 1–1.2) for jasmine rice from conventional farming. Sarus rice is in high demand, with 60% sold online and 40% on-site, significantly boosting farmer incomes and enhancing market resilience. This price advantage provides substantial financial benefits to local farmers while promoting biodiversity-friendly farming practices.



Figure 2. “Sarus rice” (organic rice).
(©Preecha Norsingha)

Government and private sector stakeholders have supported the initiative by offering training programs on online trading and packaging, helping farmers access wider markets and adopt sustainable practices. Additionally, the establishment of the Wetland and Eastern Sarus Crane Conservation Centre, funded by Buriram Sugar Company Ltd., has become a focal point for education, ecotourism, and community income generation, while raising awareness of conservation efforts.

To further support conservation, the project compensates farmers for crop losses caused by Eastern Sarus Cranes, encouraging coexistence and cooperation. This compensation has directly improved crane survival and breeding success. Protective measures, such as the installation of NCAPS cameras, safeguard bird nests during hatching periods, demonstrating the project's comprehensive approach to conservation and community well-being.

d) Building resilience in people, communities, and ecosystems

The Buriram initiative strengthens resilience by integrating sustainable agriculture, biodiversity conservation, and community support. Farmers benefit financially through the premium-priced "Sarus rice" and compensation schemes for crop damage caused by cranes, ensuring continued participation in conservation. Training programs in marketing and sustainable practices enhance their ability to adapt to economic and environmental challenges.

Ecologically, organic farming improves soil health, water quality, and wetland regeneration while supporting the recovery of the Eastern Sarus Crane population. Measures like NCAPS cameras protect bird nests, boosting biodiversity and ecosystem stability. The Wetland and Eastern Sarus Crane Conservation Centre promotes education and ecotourism, providing alternative income and fostering community awareness. By aligning conservation with local livelihoods, the project ensures people, ecosystems, and communities are better equipped to adapt to and recover from challenges, securing long-term sustainability. The integration of compensation schemes for crop losses and income diversification through organic farming strengthens community resilience. By linking conservation efforts with tangible economic benefits, the project ensures long-term sustainability for both communities and ecosystems.

Effective collaboration among agencies and stakeholders at all levels has demonstrated that managing critical habitats for the Sarus Crane (and two other endangered species in the area namely, spoon-billed sandpiper bird and Thai water onion) can support broader ecosystem restoration while maintaining productive landscapes and farmer livelihoods. The Eastern Sarus Crane's status on Thailand's Red List has improved from "extinct in the wild" to "critically endangered," largely due to a successful reintroduction program in Buriram. Building on this progress, Thailand's Office of National Resources and Environmental Policy and Planning is now advocating for the designation of new migratory bird flyway sites under the East Asian–Australasian Flyway, specifically in Buriram and Khok Kham.

e) Responsible and effective governance and institutions

The Buriram initiative fosters responsible governance through active community participation in conservation efforts. Local farmers are engaged in decision-making via meetings, workshops, and farmer cooperatives, with local leadership ensuring equitable representation. This participatory approach empowers communities to take ownership of both agricultural and conservation practices, ensuring long-term success.

The initiative benefits from a strong policy framework, supported by national policies focused on biodiversity conservation and the protection of endangered species like the Eastern Sarus Crane. Provincial guidelines align agricultural practices with conservation objectives, providing a solid foundation for sustainable land use. The establishment of the Eastern Sarus Crane Conservation Centre is a collaborative effort uniting government agencies, private sector partners, academic institutions, and local communities. Buriram Sugar Plc contributed 10 million baht in funding, while the "Conserving Habitats for Globally Important Flora and Fauna in Production Landscapes" project provided staff training and operational support to enhance the centre's conservation efforts (Treerutkuarkul 2019).

Funding for farmer compensation is secured through public-private partnerships, with the government offering conservation grants and private entities such as Buriram Sugar Company Ltd. contributing to both the Wetland and Eastern Sarus Crane Conservation Centre and compensation for crop damage caused by the cranes.

Key actors in the success of this initiative include the Zoological Park Organization (ZPO), local government agencies, NGOs, and academic institutions, all of which play vital roles in supporting

conservation, conducting research, and monitoring the impact of the program. The zoning of land for the Eastern Sarus Crane (including two other endangered species, i.e. Spoon-Billed Sandpiper, and Water Onion) across five provinces has been proposed to the Department of Town and Country Planning for integration into the provincial development plan. The long-term success of the initiative relies on continued funding, strong legal frameworks, and ongoing community engagement, ensuring that conservation goals align with local livelihoods.

In addition to conservation, there is substantial potential for developing community-based ecotourism focused on the Eastern Sarus Crane and wetlands, creating a sustainable income stream for local people. This ecotourism model not only strengthens conservation efforts but also contributes to the Gross Provincial Product (GPP) of Buriram, fostering both economic growth and environmental stewardship.

The long-term sustainability of this initiative depends on maintaining a balanced approach that integrates wetlands conservation, active local participation in bird conservation and organic farming, and the equitable distribution of benefits derived from ecotourism. Community-based ecotourism offers opportunities for income diversification while increasing awareness of conservation issues. Ensuring both ecological and community resilience requires a collaborative effort that ties conservation goals directly to the economic well-being of the local population.

Conclusion

The Eastern Sarus Crane Reintroduction Project, implemented by The Zoological Park Organization (ZPO) and the Department of National Parks, Wildlife and Plant Conservation since 2011, highlights the integration of biodiversity conservation and sustainable agricultural practices. By promoting organic farming and the branding of “Sarus rice,” the initiative aligns with sustainable development goals by reducing agriculture’s environmental footprint and supporting wetland health. Farmers adopting these practices not only contribute to conservation but also benefit financially, earning higher net incomes through premium-priced rice.

This project exemplifies the five sustainability criteria: resource use efficiency, wetland protection, supporting rural livelihoods, building resilience, and responsible governance. Of these, supporting rural livelihoods and responsible governance are the most crucial for ensuring long-term sustainability. The rebranding of rice and improved market access, coupled with government and private sector support, strengthens the local economy and empowers farmers, which is key to sustaining conservation efforts. Additionally, the development of community-based ecotourism offers further opportunities for livelihood diversification and supports ecosystem preservation.

Building resilience through compensation for crop losses and capacity-building initiatives in sustainable practices has strengthened the community’s ability to cope with challenges, ensuring the initiative’s continuity. Wetland protection and resource use efficiency are equally important, as sustainable farming practices and the protection of the Sarus Crane’s habitat contribute to both environmental and agricultural sustainability.

For this project's continued success, further emphasis on resource use efficiency, particularly through expanding organic farming and ecotourism, could enhance its sustainability. Strengthening governance structures, ensuring long-term funding, and fostering deeper community participation are vital for reinforcing the project's success and ensuring its resilience over time. The balance between ecological conservation and economic development is critical to achieving lasting sustainability, with a focus on livelihoods and governance serving as the foundation for long-term impact.

References

- Austin JE, Morrison KL, Harris JT, editors (2018) *Cranes and agriculture: a global guide for sharing the landscape*. Baraboo, Wisconsin, USA: International Crane Foundation. 303 p.
- Harris J, Mirande C (2013) A global overview of cranes: status, threats and conservation priorities. *Avian Research* **4**, 189-209.
- Li H, Leshan J, Wyatt A, Trisurat Y (2023) Case studies for sustainable wetland agriculture and related water management in China, Thailand, and Viet Nam. Bangkok, FAO. Available at: <https://doi.org/10.4060/cc4235en>.
- Treerutkuarkul A (2019) Conserving habitats for globally important flora and fauna in production landscapes. Project Result Report, United Nations Development Program (UNDP) Thailand. Available at: https://www.undp.org/sites/g/files/zskgke326/files/migration/th/UNDP_TH_Flora-and-Fauna-Booklet_Engl.pdf

Case 7. Floodwater retention in paddy fields in Bang Rakam district of Phitsanulok province, Thailand

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Site details

Item	Details
Site name	Bang Rakam: flood retention in abandoned paddy fields
Contracting Party/Country	Kingdom of Thailand
GIS Coordinates	N/A
Site ID	N/A
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	~ 8,700 ha (Project phase 1) ~ 42,400 ha (Project phase 2)
Wetland type	Rivers, streams, floodplains
Agricultural system type	Rainfed intensive; Irrigated

Main key message

The Bang Rakam Model flood management project in north-central Thailand uses abandoned paddy fields to mitigate the impacts from floods in the wet season and discharge water for irrigation in the dry season. In this way, rice fields not only produce food but also water storage which prevents flooding damage downstream. Upstream rice farmers need support to manage this regulating ecosystem service, e.g. by supplying alternative livelihoods or by payment for ecosystem services.

The challenge presented by rice production in the Bang Rakam floodplain in Thailand

The Bang Rakam area is a natural floodplain located between the Yom River and Nan River Basin in Phitsanulok province in the Kingdom of Thailand, covering approximately 8,700 ha. Floods and droughts are a common phenomenon in Bang Rakam district. Floods usually occur during the rainy season between August and October. Droughts occur from January to April, due to the discontinuity of rain and the lack of water infrastructure in the Yom River Basin, resulting in a lack of capacity to store water. In recent years, Thailand endured two major floods. In 1995, after several tropical cyclones impacted the country, heavy rain damaged the spillage of the Sirikit Dam in Uttaradit province and created high discharges into Thailand's rivers, resulting in a major flood. The second

severe flood occurred in 2011, affecting 65 provinces in the northern, northeastern, and central regions, or about 35 percent of the country's land area.

Rice farmers depend on rainwater for cultivation. Both droughts and floods negatively affect crops in the Bang Rakam district. Older farmers living in this area are used to two-month flooding periods, which usually occur in September and October. When they have access to irrigation, about 90 percent of farmers grow two rice crops per year, making sure they harvest wet season rice before September. Only a small number of the farmers (10 percent), whose land is not affected by flooding, manage to grow three crops per year (Figure 1).

Rice period													% of farmers
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
3x harvest before BRM 60	2 nd rice cultivation				3 rd rice cultivation				1 st rice cultivation				10%
2x harvest before BRM 60		1 st rice cultivation						2 nd rice cultivation					90%
2x harvest with BRM 60	1 st rice cultivation								2 nd rice cultivation				95%
3x harvest with BRM 60	2 nd rice cultivation				3 rd rice cultivation				1 st rice cultivation				5%

Figure 1. Cultivation calendar in Bang Rakam district. The rainy season is between August and October. The dry season is from January to April. The dark blocks indicate the period of prolonged water storage on the rice farms. Source: Voogd (2019).

This case study focuses on the riverbank of the Yom River in the north–central part of Thailand, where farmers' paddy rice fields are used to contain floods. After the rice harvest, the fields can be used to retain floodwater during the rainy season, which causes prolonged flood duration on these farms. The concept of the "monkey cheeks", or water retention, was implemented after the flood of 2011 through the Bang Rakam Model 54 (Phase 1), one of Thailand's prominent flood risk management projects. Through this project, which covered some 8,700 ha, large amounts of water from the Yom River were retained to prevent flooding downstream during the rainy season. The number 54 denotes the Buddhist year 2554 BE (equal to the year 2011) in which the model was initiated.

After the end of Model 54, the government assigned the Royal Irrigation Department (RID) under the Ministry of Agriculture and Cooperatives to redesign and operate flood retention in this area, for which the RID hired consulting companies to conduct a feasibility study. The study involved the preliminary identification of flood retention areas, an environmental impact assessment and a public participation process. The feasibility study was completed in April 2017. The project has been officially resumed with the new name, Bang Rakam Model 60 (BRM 60, where 60 is the Buddhist year 2560 B.E., equal to the year 2017), and the project area was expanded. Phase 2 of the project covers approximately 42,400 ha, and is a hybrid programme that contains both structural and non-structural measures to control floods during the rainy season and harvest rainwater for the dry season to provide water supply to farmers' fields. The structural measures include heightening roads, water gates and dykes to steer floods in different directions. The non-structural measures include changing the cultivation calendar.

a) Options for increasing resource use efficiency

The objective of the Bang Rakam Model projects was to mitigate flood and drought problems by storing water and preventing floods during the wet season, and making irrigation water available during the dry season. This resulted in an increase in water use efficiency at the basin level. To accommodate flooding in the harvested paddy fields, an adjustment of the cultivation calendar was needed. This included advancing the planting of the first rice crop and postponing the second crop to create a longer interval for flood retention (Figure 1). An early cultivation calendar (April–July), as recommended by RID, allows farmers to harvest rice before the flood season (September–October), during which paddy fields are used for water retention. The water retention areas are drained in November to prepare for the second cultivation, which starts from 1 December. During the flood season, the project may retain floodwater in the paddy fields for use in the dry season.

The steps below elaborate on the changes in the cultivation calendar, and the water retention and drainage strategies.

- First, the RID delivers water to paddy fields on 20–31 March, aiming at early cultivation in April instead of May, in order to avoid flash floods.
- Second, farmers start rice cultivation at the beginning of April (rather than May) and use fast-growing rice varieties (i.e. three and a half months rather than four months) and harvest paddy grains before the end of July, instead of in August. During this period, the RID manages water resources and prevents floods.
- Third, after harvesting (by 15 August), the RID diverts water from the Yom River and its tributaries to the abandoned paddy fields and swamps for two months (15 August–31 October). The target amount of water volume varies according to the rainfall amount. During this period, the government puts fingerlings into the water, so farmers can earn additional income of THB 300–500 per household per day from fishing.
- Fourth, the RID drains water from the abandoned paddy fields and swamps to rivers and tributaries (1–30 November) and retains floodwater in the paddy fields for the second crop cultivation (December–March).

b) Protecting wetlands and mitigating pressure/impact on wetlands

This case does not involve any formally protected wetlands.

c) Supporting rural livelihoods, equity, and social well-being

To support farmers to mitigate the impacts of keeping their farms flooded, government agencies encourage farmers to advance their rice cultivation calendar by providing irrigation water in the dry season (January–April, 3d row in Figure 1) and promoting fast-growing, short-duration rice varieties by providing seeds. Although farmers were able to generate some income from the flooded fields by catching fish, which came from government-provided fingerlings, the prolonged flood season and a lack of alternative livelihoods presented challenges for them. Therefore, for a long-term sustainable approach, more incentive measures need to be established such as institutionalized payment for ecosystem services.

d) Building resilience in people, communities, and ecosystems

In Thailand, innovative wetland and agricultural management approaches have demonstrated the potential to build resilience in people, communities, and ecosystems. The Bang Rakam Model exemplifies this by utilizing abandoned paddy fields for flood retention during the rainy season, mitigating the impacts of severe flooding while discharging water for irrigation in the dry season, allowing for cultivation of a second crop. This was done by applying several nature-based solutions

such as raising roads, water gates and dykes to steer floods in different directions, another intervention in addition to changing the cultivation calendar. This model, recognized as a national success, minimizes flood damage and enhances water resource management across affected areas. A study conducted between 2020 and 2022 by researchers from Thailand's Office of the National Water Resources and the German international cooperation agency (GIZ), with technical guidance from the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), highlighted the benefits of floodplain interventions. According to the survey, 70% of respondents believed the intervention positively impacted the local economy, while 34% reported a reduction in disaster risks. This underscores the value of floodplain management in enhancing economic resilience and mitigating hazards (UNEP-WCMC 2023).

In Buriram province, the Huai Chorakhemak Non-Hunting Area integrates organic rice farming with conservation efforts for the endangered Eastern Sarus Crane. By rebranding organic rice as "Sarus rice," farmers benefit from higher market prices, while wetland conservation is advanced through ecotourism and community-based initiatives. Compensation schemes for crop damage caused by crane activity further align conservation with local livelihood improvement.

Both cases underscore the value of collaborative, nature-based solutions to enhance resilience, sustain livelihoods, and protect biodiversity. These models highlight the importance of long-term support, such as payment for ecosystem services and participatory governance, to ensure sustainable development.

e) Responsible and effective governance and institutions

To enhance the sustainability of wetland and agricultural management in Thailand, the institutionalization of Payment for Ecosystem Services (PES) could serve as a key mechanism in addition to the existing programs and projects. PES should be established as an institutionalized mechanism to compensate farmers for losses incurred during prolonged flooding in paddy fields while ensuring that downstream beneficiaries contribute to the resilience of the system. Effective governance arrangements for implementing PES require active participation from both government and non-government actors. Farmers, as primary stakeholders, should be involved in co-designing PES schemes to reflect their needs and ensure equitable compensation. This can be achieved through participatory forums and farmer cooperatives that enable collective decision-making.

Government actors, including Thailand's Department of Water Resources and local administrative bodies, play a critical role in policy formulation, monitoring, and funding the PES framework. Non-governmental organizations (NGOs) and community-based organizations (CBOs) can act as intermediaries, facilitating communication between farmers and beneficiaries, as well as providing technical support for implementation.

Upstream-downstream dynamics are central to the governance framework. For example, upstream farmers participating in flood retention initiatives could receive payments from downstream users, such as industries or urban municipalities, benefiting from reduced flood risks and stable water supplies. Coordination across these stakeholders is essential, requiring mechanisms like river basin committees or multi-sectoral platforms.

Formal governance structures are necessary to institutionalize PES. These could include national policies, legislative support, and regulatory frameworks that define roles, responsibilities, and financial mechanisms. For example, legislation could mandate contributions from downstream beneficiaries or incentivize private sector engagement through tax benefits or subsidies.

To make PES work effectively, several factors are needed:

1. Clear policies and legislation: national guidelines to support PES implementation and ensure compliance;
2. Capacity building: training programs for farmers and local authorities to understand and operationalize PES;
3. Financial mechanisms: establishment of a sustainable funding pool through government budgets, international donors, and private sector contributions;
4. Monitoring and evaluation: transparent systems to track outcomes, ensuring accountability and measuring ecosystem benefits.

Institutionalizing PES within Thailand's wetland governance structure would align economic incentives with conservation goals, fostering long-term resilience and sustainable wetland management.

Conclusion

The BRM 60 project was nationally recognized as a showcase for large-scale water resource management in Thailand and was expanded to cover many floodplains in other river basins which were identified as flood-prone areas. The project substantially reduces flooding and minimizes damage costs. It has been a success for the RID (Royal Irrigation Department under the Ministry of Agriculture and Cooperatives) and is becoming a key component for water resource management policies in Thailand. The Thai cabinet has been considering a plan to expand this “monkey cheeks” approach in 69 floodplains in Nakhon Sawan, Uttaradit, Phitsanulok and Sukhothai provinces, with financial support from the Green Climate Fund (ONEP 2015). To sustain the approach in the long run and apply the approach in other areas, an enhanced financial compensation package is highly recommended for farmers affected, for instance, a payment for ecosystem services by downstream residents to affected farmers is recommended due to the benefit of the controlled floods.

References

- Li H, Jin Leshan, Wyatt A, Trisurat Y (2023) Case studies for sustainable wetland agriculture and related water management in China, Thailand, and Viet Nam. Bangkok, FAO. <https://doi.org/10.4060/cc4235en>
- Voogd S (2019) The Bang Rakam Model: Farmers' perceptions on a flood retention policy in Phitsanulok and Sukhothai Province, Thailand. MSc thesis Environmental Geography, Graduate School of Social Sciences. Amsterdam, University of Amsterdam. http://deltasoutheastasia-doubt.com/wp-content/uploads/UploadedDocuments/MSc_Thesis_Sjoerd_Voogd_10798617-2.pdf
- ONEP (2015) National Report on the Implementation of the Ramsar Convention on Wetlands. Submitted for the 12th Meeting of the Conference of the Contracting Parties, Uruguay. Office of the Natural Resources and Environmental Policy and Planning. Bangkok.
- UNEP-WCMC (2023) Lessons for ecosystem-based adaptation along Thailand's changing rivers. Available at: <https://www.unep-wcmc.org/en/news/lessons-for-ecosystem-based-adaptation-along-thailands-changing-rivers> (Accessed: 12 December 2024).

Case 8. Maintaining ponds in agriculture landscapes for the benefit of local communities and wetlands

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Item	Details
Site name	Maoli Lake (on the edge of Dongting Lake plain)
Contracting Party/Country	Hunan Province, P.R. China
GIS Coordinates	29°24'N 111°55'E
Site ID	2505
RIS last updated	2022
RIS source	https://rsis Ramsar.org/ris/2505
Surface area of case site (ha)	4,776 ha
Wetland type	Rivers, streams, floodplains; Lakes
Agricultural system type	Rainfed intensive

Main key message

Small pond within agriculture catchments are the key engine for recycling of nutrients and maintaining a wide range of ecosystem services that benefit both people and nature. Such system requires effective maintenance through institutional and legal support, including eco-compensation mechanisms.

The challenge presented by food production in relation to Maoli Lake and its floodplain

Maoli Lake, Wetland of International Importance (Figure 1), which is located at the edge of Dongting Lake plain near Jinshi City in Hunan Province, was isolated from Dongting Lake during the past two centuries due to wetland reclamation and is now an independent small lake basin system. The total area of Maoli lake basin is 18,900 ha and consists of villages, rice paddies, forests, ponds, rivers and a lake. The sustainable management of this system is critically important for the wintering birds in the region (Figure 2), particularly in view of the fact that three other Wetlands of International Importance in the Dongting Lake dried up in the winter season as a result of dam operations and changes in rainfall and temperature due to global climate change (Zheng et al. 2023).

Inflows into the lake include 6 rivers and 25 creeks, ensuring the integrity of the lake basin ecosystem. The lake system provides habitat for 77 species of fish, with 3 native species, as well as 129 bird species, including IUCN red-listed species such as the black-necked crane (*Grus nigricollis*), the lesser adjutant stork (*Leptoptilos javanicus*), and the Oriental stork (*Ciconia boyciana*) (Chen et al., 2019; Fu

et al., 2018). These species are vital to maintaining the biodiversity and ecological balance of the region, and their presence underscores the importance of conserving the lake ecosystem. Efforts to protect the integrity of the lake system are critical for maintaining these habitats, which provide essential ecosystem services such as water purification, flood control, and biodiversity conservation (Xiao et al., 2023).

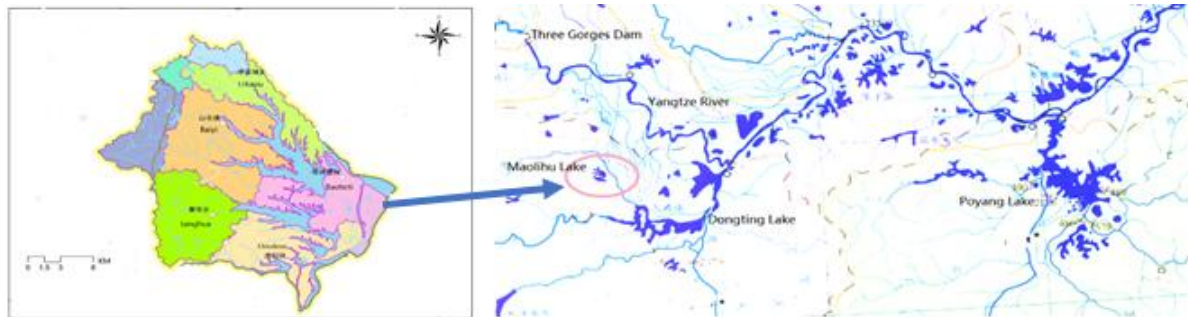


Figure 1. Location of Maoli Lake, Wetland of International Importance, in the Central Yangtze Region, P.R. China



Figure 2. Maoli Lake scenery (left) and migratory birds habitat (right). (© Lei Guangchun)

Throughout the catchment, traditional water ponds have been a common resource which all farmer households benefit from for irrigation, flood storage, fishery and drinking water (Figure 3). Local communities have a tradition of maintaining the ponds by dredging pond sediments every three or four years and using them as organic fertilizers. However, this tradition was lost during the 1980-2010 period due to rural reforms and changes in land tenure. After the reform, each household managed its own land, and the connection among water ponds, river and creeks was cut off. Households started applying chemical fertilizers and pesticides (rather than using organic fertilizer), which led to farmland degradation, lake water quality decline, and a decrease in fish and water bird diversity (Chen et al., 2019; Fu et al., 2018; Zheng et al., 2021).

In 2013, when the area was designated as a National Wetland Park, a series of restoration programs was carried out to restore the rice paddy-pond-river system for irrigation, flood control, drinking water supply, biodiversity conservation, and cultural values. This restoration of the agricultural landscape was combined with rural sewage water treatment facilities that only allow the inflow of treated water into the river. Ten years after the start of this effort, water quality has improved significantly. The system has become more sustainable, and the ecological character of wetlands was maintained (Chen et al., 2019; Fu et al., 2018; Zheng et al., 2021).



Figure 3. Pond near a town within Maoli Lake basin. (© Lei Guangchun)

Actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

Integrating small ponds into agricultural landscapes offers a sustainable solution to enhance resource use efficiency, addressing both water management and nutrient recycling challenges. Small ponds are pivotal in agricultural systems for water storage during dry seasons and flood mitigation during rainy periods, acting as natural reservoirs that improve water availability for irrigation and reducing the risk of crop damage from excessive rainfall (Fu et al., 2018; Xiao et al., 2023). A critical management practice involves dredging sediments from the ponds and repurposing them as organic fertilizers for rice paddies. These nutrient-rich sediments enhance soil fertility, reduce dependency on chemical fertilizers, and lower agricultural production costs (Chen et al., 2019). This practice also addresses non-point source pollution, as sediment removal improves water quality and prevents nutrient buildup in ponds (Zheng et al., 2021). Maintaining these ponds supports ecosystem services such as nutrient cycling and water purification, essential for sustainable agricultural practices (Fu et al., 2018).

b) Protecting wetlands and mitigating pressure/impact on wetlands

Beyond productivity benefits, small ponds play a vital role in biodiversity conservation. They provide habitats for aquatic and terrestrial species, contributing to ecological stability within agricultural landscapes. This biodiversity effect can spill over to adjacent wetlands, supporting species conservation and ecosystem resilience. Integrating ponds into watershed management frameworks helps create a network of interconnected habitats that buffer and sustain wetland ecosystems (Liu et al., 2013).

Small ponds within agricultural landscapes also play a critical role in wetland protection by reducing environmental pressures and mitigating impacts on these fragile ecosystems. The ponds act as natural buffers, regulating water flow, improving water quality, and reducing sediment and nutrient runoff into larger wetland systems (Fu et al., 2018; Xiao et al., 2023). By retaining water during heavy rainfall and releasing it during dry periods, ponds alleviate the pressure on downstream wetlands, helping maintain hydrological balance. Dredging pond sediments not only supports nutrient recycling but also prevents nutrient overloading, which can lead to eutrophication in downstream wetlands (Chen et al., 2019; Zheng et al., 2021). The practice ensures that wetlands are protected from the adverse impacts of agricultural non-point source pollution, preserving their ecological integrity.

Effective pond management reduces the pressures on wetlands, ensuring that they continue to provide essential services such as water filtration, flood regulation, and habitat provision. Incorporating these measures into integrated agricultural and watershed management strategies is essential for long-term wetland protection and sustainability.

c) Supporting rural livelihoods, equity, and social well-being

Small ponds in agricultural landscapes play a vital role in supporting rural livelihoods, promoting equity, and enhancing social well-being by providing essential resources and ecosystem services. The ponds contribute directly to food security and income generation through activities such as aquaculture and irrigation, which sustain agricultural productivity and diversify livelihoods (Fu et al., 2018; Chen et al., 2019). By serving as a water source for crops during dry seasons, ponds reduce the vulnerability of smallholder farmers to climate variability, ensuring more stable agricultural outputs. The use of pond sediments as organic fertilizers improves soil health and lowers production costs, making farming more affordable and accessible for low-income households (Chen et al., 2019).

In addition to their direct benefits, small ponds improve environmental conditions by reducing non-point source pollution and supporting biodiversity, which strengthens the natural systems that rural communities depend on (Chen et al., 2019; Zheng et al., 2021). Ponds also enhance equity by acting as shared community resources, promoting cooperative management and fair access among users (Liu et al., 2013). Their ancillary benefits, such as water for domestic use and habitats for aquatic biodiversity, indirectly contribute to community well-being (Xiao et al., 2023). By integrating sustainable pond management practices, agricultural landscapes can become hubs of social and economic resilience, enhancing rural equity and overall well-being.

d) Building resilience in people, communities, and ecosystems

Small ponds embedded within agricultural landscapes are vital for building resilience among people, communities, and ecosystems. The ponds provide crucial water resources for irrigation during dry periods, mitigate flooding during heavy rains, and stabilize agricultural productivity, thereby reducing the vulnerability of rural communities to climate variability (Fu et al., 2018; Chen et al., 2019). The use of pond sediments as organic fertilizers reduces reliance on chemical inputs, fostering more sustainable farming practices that safeguard long-term ecosystem stability (Zheng et al., 2021). Ecologically, small ponds function as biodiversity hotspots that buffer against environmental disruptions and contribute to the stability of surrounding landscapes, including wetlands and agricultural systems (Xiao et al., 2023).

Communities benefit socially and economically from ponds as shared resources, promoting cooperation and equity in their management (Liu et al., 2013). By integrating pond management into broader watershed strategies, communities and ecosystems are better equipped to adapt to challenges like climate change, resource scarcity, and pollution. This interconnected approach fosters resilience at multiple scales, ensuring sustainable outcomes for both human and natural systems.

e) Responsible and effective governance and institutions

Effective governance and institutional support are critical for ensuring the sustainability of small ponds and their role in agricultural and ecological resilience. Clear policies and well-defined roles for stakeholders are essential to harmonize pond management with broader environmental and agricultural objectives. National and local governments can create frameworks that regulate pond use, protect their ecological functions, and integrate them into watershed management strategies (Zheng et al., 2021).

Community participation is vital to successful governance. Involving local farmers in decision-making processes fosters a sense of ownership and ensures that pond management practices align with community needs. Farmer cooperatives and local committees can act as governance platforms to

coordinate pond management activities, such as sediment dredging and water-sharing agreements (Liu et al., 2013).

Cross-sectoral collaboration among governmental agencies, NGOs, and private sector partners is also essential for long-term governance. Agencies responsible for agriculture, water resources, and biodiversity must work together to create integrated policies that maximize the multifunctionality of ponds. NGOs and private entities can support this effort by providing funding, capacity-building programs, and technical assistance (Chen et al., 2019).

Formal regulation and enforcement mechanisms are necessary to maintain pond functionality and prevent misuse, such as pollution or over-extraction of water. Long-term sustainability requires adaptive governance to account for climatic and socioeconomic changes (Xiao et al., 2023).

Eco-compensation mechanisms, such as payments for ecosystem services (PES), can incentivize sustainable practices while providing financial support for communities that maintain ponds. These mechanisms create a shared responsibility model, where beneficiaries of ecosystem services contribute to their preservation, strengthening local governance structures. In practice, farmers can be rewarded through eco-compensation schemes or direct support programs that align agricultural production with environmental conservation goals. Financial incentives are offered for ecosystem service provision, such as water quality regulation and biodiversity preservation. For example, eco-compensation schemes in China have effectively encouraged farmers to reduce agricultural non-point source pollution and adopt practices that minimize wetland impacts (Zheng et al., 2021). Similarly, financial rewards and subsidies for maintaining pond ecosystems have proven crucial for conserving neglected wetland areas, promoting sustainable land management (Chen et al., 2019). These approaches ensure that conservation efforts are integrated with agricultural practices, offering a balanced solution for both environmental and economic sustainability.

Conclusion

Traditional agricultural systems that combine rice paddies, ponds, and natural watercourses are invaluable for maintaining the ecological integrity of Wetlands of International Importance while promoting sustainable food production. These systems balance agricultural productivity with environmental stewardship, exemplified by practices like sediment dredging, which simultaneously enhance water quality, reduce pollution, and provide organic fertilizers. This approach aligns with landscape-level management strategies, where preserving and managing small ponds fosters resilience in agricultural systems, reduces environmental impacts, and supports biodiversity conservation (Xiao et al., 2023). This time tested system, sustainable for thousands of years in southern China, demonstrates how harmonizing agriculture with natural water systems can support high-quality food production and environmental sustainability.

While this model has stood the test of time, its continued success requires modernization and support. Introducing incentives such as green product certifications, eco-compensation schemes, and market-based rewards for sustainable practices can enhance the economic viability of these systems. Such measures will not only ensure their resilience in the face of modern challenges but also support the livelihoods of the communities that manage them. The integration of traditional knowledge with innovative policy and market incentives can secure the future of these agricultural landscapes, ensuring their role in food security, biodiversity conservation, and the sustainable management of Wetlands of International Importance.

References

- Chen W, He B, Nover D, Lu H, Liu J, Sun W, Chen W (2019) Farm ponds in southern China: Challenges and solutions for conserving a neglected wetland ecosystem. *Science of the Total Environment* **659**, 1322-1334. doi:10.1016/j.scitotenv.2018.12.394
- Fu B, Xu P, Wang Y, Yan K, Chaudhary S (2018) Assessment of the ecosystem services provided by ponds in hilly areas. *Science of the Total Environment* **642**, 979-987. doi:10.1016/j.scitotenv.2018.06.138
- Liu Y, Duan M, Yu Z (2013) Agricultural landscapes and biodiversity in China. *Agriculture, Environment and Ecosystems* **166**, 46-54. doi:10.1016/j.agee.2011.05.009
- Xiao H, Luo Y, Jiang M, Su R, Li J, Xiang R, Rongui HU (2023) Landscape patterns are the main regulator of pond water chlorophyll α concentrations in subtropical agricultural catchments of China - *Journal of Cleaner Production* **425**, 139013. doi:10.1016/j.jclepro.2023.139013
- Zheng Y, Lei G, Yu P (2021) Eco-Compensation Schemes for Controlling Agricultural Non-Point Source Pollution in Maoli Lake Watershed. *Water* **13**, 1536. doi:10.3390/w13111536
- Zheng F, Gan Y, Yang L, Wu J (2023) Impact of climate change on the major eco-hydrological parameters in the Dongting Lake Basin. *Applied Sciences* **13**, 9515. doi:10.3390/app13179515

Case 9. A constructed wetland and pond for improved water management in a seasonally water-scarce environment (Stora Tollby organic farm, Sweden)

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Site details

Item	Details
Site name	Wetland Fole Stora Tollby
Contracting Party/Country	Sweden
GIS Coordinates	57°37'26.7"N 18°32'11.3"E
Site ID	N/A
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	5.6
Wetland type	Water storage bodies (small farm ponds)
Agricultural system type	Rainfed intensive

Main key message

A constructed wetland and pond are created in a water-scarce agricultural area to combine the benefits of an irrigation pond, noble crayfish production, and increased biological diversity. The pond allows farmers to grow speciality crops and employ more local workers while improving irrigation efficiency and enhancing wildlife.

The challenge presented by food production in relation to water scarcity Food and vegetable production is an important economic sector on the Island of Gotland, just east of mainland Sweden in the Baltic Sea. In 2019, Gotland County had around 1,400 agricultural enterprises, constituting about 2% of Sweden's total. These enterprises manage 3% of the national arable land and 6% of the pasture land, larger than the national average. About 36% of the pasture and 14% of the arable land are farmed organically. The total agricultural area is 86,000 ha. Ley (usually a mixture of timothy, *Phleum pratense* and clover, *Trifolium* spp.) is the most common crop (34,000 ha), and winter wheat (*Triticum aestivum*) is the second main crop (15,500 ha). Potato (*Solanum tuberosum*) and carrots (*Daucus carota sativus*) are cash crops occupying 1,700 ha.

Stora Tollby Farm (140 ha) in Gotland is dedicated to sustainable agriculture. Located in Fole, 15 km east of Visby, the farm's soil ranges from loamy moraine for cereals to stone-free sandy deposits for vegetables and potatoes. The region has a mild maritime climate with an average annual temperature of 8°C. All cultivation is meticulously managed under the IP and HACCP environmental management systems, with each action carefully documented and prioritised based on environmental impact. Soil analyses ensure that nutrients are applied appropriately and that cadmium levels are within safe

limits. The farm employs only mechanical weeding methods and is open to exchanging expertise. Stora Tollby Farm is not just about sustainable agriculture but also about innovative conservation.

The farm has irrigation across its cultivated lands to ensure optimal nutrient uptake by the crops and prevent nutrient runoff into waterways. Buffer zones of perennial grass line the streams to trap nutrients and soil. Natural green corridors with diverse vegetation crisscross the arable land, while a park contains various tree species. Wheat fields feature edge zones where weeds grow freely to benefit partridges and other birds. A section of forest has been designated as a permanent nature reserve to preserve ancient Gotland coniferous woodland.

Modern machinery optimises diesel and electricity use, reducing environmental impact. Diesel tractors are fitted with fuel-efficient, low-emission engines and run on environmentally friendly fuel blends. Historic buildings from the 1800s have been preserved and repurposed as homes, storage, and processing facilities. The farm strives for a positive energy balance in food production and encourages customers to use minimal, recyclable packaging. Potatoes unsuitable for sale are repurposed as animal feed, while waste is returned to the fields as fertiliser, ensuring no emissions.

The well-stocked farm store offers locally grown produce cultivated with care, reflecting the love that goes into each item. Visitors will find potatoes served at Nobel dinners and royal luncheons, and they can hand-pick fresh corn from the garden. The store is open daily and operates on a self-service basis.

Interest in the island's wetlands/mires was first expressed by Linnaeus on his trip to Gotland in 1742, but mainly with a focus on plants. Due to the increased interest in increasing food, feed and vegetable production in Sweden, most of the original peatlands and wetlands were drained, starting at the beginning of the 19th century. The soils are fertile due to the high pH in the calcareous rich soil on the island, but the area often suffers from very dry summers. Agricultural activities have reduced the area of wetlands, leading to reduced biological diversity. The risk of nutrient leaching is high with crops yielding less than optimal due to drought. It is not legal to use groundwater for irrigation. The challenge is to produce enough food with limited water availability, and one option to increase yield is to create irrigation ponds that harvest water during autumn and winter.

This case study describes the creation of a human-made wetland that works as an irrigation pond but also supports local biodiversity. Drainage water is collected during high-flow periods between November and December and stored in farm ponds, allowing natural waterways to remain untouched in the low-flow summer periods and reducing eutrophication. Washing water from the vegetable washer is also collected in a pond and reused for irrigation, eliminating any discharge. The ponds have developed into wetland habitats, providing nesting and resting sites for birds like the whooper swan (*Cygnus cygnus*), common crane (*Grus grus*), and tufted duck (*Aythya fuligula*). With EU and Gotland County Council support, the farm has now built a 5.6 ha, 5-meter deep combined irrigation dam and wetland area, doubling its current irrigation capacity from 100,000 to 200,000 m³ to meet future challenges. The new irrigation pond was built during one year (Figure 1) and is owned by the farmer, but other ponds on the island can have shared ownership. The pond has been invaluable during recent dry summers, supporting a larger area (200 ha) than only the farm itself. The pond allows the production of speciality crops like sweetcorn (*Zea mays* var. *saccharata*), onion (*Allium cepa*), carrot (*Daucus carota*), Jerusalem artichoke (*Helianthus tuberosus*) and asparagus (*Asparagus officinalis*), and also generates employment for local workers while improving irrigation efficiency and enhancing wildlife. The maximum yearly irrigation volume needed so far has been 160,000 m³, leaving 40,000 m³ of water to be sold to irrigating neighbours. Besides water, the ponds hold crayfish (*Astacus astacus*) for home consumption only. The variation in the water table during irrigation is not beneficial for maximizing crayfish production.



Figure 1. Beginning of construction of pond. (© Andreas Wiklund)

Actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

The construction of the combination pond increases the availability of water while creating a wetland in the area. The irrigation system enables the farm to manage water availability for the crops carefully. Active participation in irrigation trials helps to understand watering schedules and quantities and refine irrigation practices. By performing nutrient balance assessments, the farmer can optimise nutrient application. The harvests consistently yield more produce than the fertilisers applied, demonstrating that the soil is adequately depleted of nutrients and that nutrient leaching is minimised (ten Damme et al., 2022). As a result, crops are healthier, better equipped to resist diseases and insect infestations, and more competitive against weeds due to stronger establishment. Improved water management also improves downstream water quality by reducing nutrient runoff.

The disadvantage of combination ponds is that they occupy more land. A 5-hectare water surface requires approximately 7 hectares of land (given an external slope of 1:4, a 4-meter crest width, and an internal slope of 1:7).

b) Protecting wetlands and mitigating pressure/impact on wetlands

The pond decreases the risk of drought and has gentle slopes, which increases the environmental value (Figure 2). This significantly enhances local biodiversity, as shown by the white-tailed eagles (*Haliaeetus albicilla*) that have started nesting in the area since the construction of the latest pond, and the numerous ducks, geese, and wading birds that the wetland now hosts. This irrigation system ensures robust, high-yield crops and contributes to a richer and more sustainable ecosystem, balancing agricultural productivity with environmental stewardship.

c) Supporting rural livelihoods, equity, and social well-being

The crayfish production increases farmer's income. The improvements in environmental quality and biodiversity contribute to a general increase in human well-being (Figure 3).



Figure 2. Pond before filling of water. (© Andreas Wiklund)



Figure 3. View of the pond with water. (© Andreas Wiklund)

d) Building resilience in people, communities, and ecosystems

The increased bird biodiversity allows bird watchers to thrive, which gives the farmer good PR. The pond also buffers high water flows when there is heavy rain.

e) Responsible and effective governance and institutions

The total cost of the pond was €250,000, of which 50% was financed by the rural development scheme administered by the board of agriculture but distributed by the county administrative board. Public support covered 90% of the costs, up to a maximum of €20,000 per hectare. The pond received this financial support because of the multiple purposes of being both an irrigation pond and the creation of a wetland with other benefits such as improved biodiversity and the possibility of buffering high water flow events. Since the construction of this pond, public support for similar schemes has been reduced, offering a maximum of €75,000 for a total investment of €250,000. Today, the region can

only support 7-8 ponds annually through public funding. Given their typically limited liquidity, this financial gap is particularly challenging for farmers. Another major challenge preventing other farms from implementing similar ponds are the bureaucratic procedures and the multiple permissions required. Administrative support from county administrative board experts was crucial in helping farmers navigate application forms and secure necessary permits.

Conclusion

Creating a combination pond significantly improved the system's water management, production, biodiversity, and resilience to summer drought periods. The challenges for further implementation of combination ponds are the required space, the financial investments needed and the bureaucratic procedures for obtaining the required permissions. Public funding and administrative support were crucial for the success of the ponds at Stora Tollby farm. Despite these challenges, implementing combination ponds can be an effective strategy for enhancing agricultural sustainability and biodiversity. Continued financial and administrative support will be vital for encouraging more farmers to adopt these beneficial systems.

References

- LRF Media (2021) *Lagring Av Vatten För Bevattning*. Available at: <https://www.lrf.se/media/z0zcxtbe/lagra-vatten-for-bevattning-rapport.pdf> (in Swedish).
- ten Damme L, Jing S, Montcalm AM, Jepson M, Andersen MN, Hansen EM (2022) Proper management of irrigation and nitrogen-application increases crop N-uptake efficiency and reduces nitrate leaching. *Acta Agriculturae Scandinavica, Section B - Soil & Plant Science* **72**, 913-922. <https://doi.org/10.1080/09064710.2022.2122864>

Case 10. Collaboration between farmers and conservationists to improve the status of the aquatic environment in a protected lake and wetland area in Sicily, Italy

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Site details

Item	Details
Site name	Convention on Wetlands Zone Laghi di Murana, Preola e Gorgi Tondi/ Integral Nature Reserve Lago Preola and Gorgi Tondi
Contracting Party/Country	Italy
GIS Coordinates	37° 36' 42.71"N 12° 38' 58.58"E http://sgi1.isprambiente.it/zoneumide/viewer/index.html
Site ID	Site was designated nationally as a Convention on Wetlands Zone but designation is not official yet
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	335 ha
Wetland type	Lakes
Agricultural system type	Horticulture (open)

Main key message

Until 1999 the wetland area suffered from water scarcity, eutrophication and heavy pollution caused mainly by agriculture. Collaboration with the farmers to limit the use of water, herbicides, fertilizers and the acquisition of land has led to restoration of good condition of the ponds, the status of endemic freshwater turtle and improved quality of wine and olive oil production.

The challenge presented by food production in relation to the protected lake and wetland area

Lake Preola and the Gorgi Tondi (Mazara del Vallo, west of Sicily) is an area of five lakes and surrounding wetlands set in a wide valley surrounded by low limestone hills, enclosed in an environment of lands densely cultivated with vineyards (in more than 40% of the total area) and olive groves (2% of the total area) (Figure 1). Among all the Italian Convention on Wetlands zones, it is the only area characterized by the presence of vineyards. The five lake basins are of karst origin. The area, one of the most important wetlands in western Sicily, has a dense swamp vegetation that surrounds the water and lush Mediterranean scrub, which covers the limestone ridges.



Figure 1. Areal photograph showing the lakes and surrounding agricultural areas. (© WWF Italia archive)

The Convention on Wetlands Zone functions as a stepping stone for migratory waterbird species and for the stopover of numerous contingents of waterbirds during the wintering phase, for the nesting of rare and threatened species such as the marbled duck (*Marmaronetta angustirostris*), the ferruginous duck (*Aythya nyroca*) and the glossy ibis (*Plegadis falcinellus*). The ornithological importance of the area was also recognized with the designation as an “Important Bird Area” (“Zona Umida del Mazarese” – IBA 162). Furthermore, the water bodies of the Convention on Wetlands Zone represent a very important habitat for the conservation of the breeding sites of endemic species such as the Sicilian green toad (*Bufo siculus*) and the Sicilian pond turtle (*Emys trinacris*), classified as endangered by the Italian red list (Rondinini et al. 2022; Figure 2).



Figure 2. The Sicilian pond turtle (*Emys trinacris*). (© Stefania D'Angelo)

Before 1999, the area was under severe water stress. Two of the five lake basins had no water for at least a decade and the other three showed eutrophication, anoxia and heavy pollution. The main pressures were: agriculture (more than 300 small farms, total area about 300 ha) consisting mainly of vineyards, with an intensive use of pesticides and fertilizers; the presence of a landfill that caused the leakage of lanthanides (metallic chemical elements with atomic numbers 57–70) in the water. These substances may have contributed to a high mortality of endemic pond turtles caused by bioaccumulation (probability of extinction of the population was estimated at 88% in an average

period of 73 years). As a result of the agricultural activities, the lakes suffered from salinization with the sea at a distance of only about 1 km from the wetland. Furthermore, the presence of cyanobacteria *Microcystis* spp. (microcistine) had been detected.

When WWF Italy assumed the management of the area (1999), the restoration of groundwater levels was immediately identified as a priority to stop the process of salinization and desertification. This was achieved by regulating the water withdrawal within the protected area, and authorizing a distribution network of water for irrigation use from a nearby dam. Consequently, a succession of sufficiently rainy winter seasons led to the stabilization of groundwater levels which resulted in the regression of the salinization and an improvement of water quality. Another important effect was the spontaneous restoration of strips of riparian vegetation. Recovery of the aquatic ecosystems resulted in the increase of several animal taxa, particularly the endemic pond turtle (*Emys trinacris*) population that increased to more than 700 specimens (reaching zero probability of local extinction). Of paramount importance was the abatement of the pressure related to agriculture in the immediate vicinity of the reservoirs, achieved through: the acquisition of 21 ha of private land; a ban on the use of herbicides; limiting tillage; organization of information meetings with farmers on the effects of pesticides on biodiversity; and providing information on funds for organic farming and on methods for maintaining ecosystem services related to water resources and decreasing soil leaching.

Actions or opportunities for actions to make the nature reserve more sustainable

a) Options for increasing resource use efficiency

One of the first directives of the Management Body was to prohibit the use of systemic herbicides. Multiple meetings with stakeholders, hitherto ignored by the institutions, served to convince them to switch to sustainable cultivation methods and enabled them to benefit from regional funding. Improved soil management put an end to problems such as runoff and groundwater pollution. The pumping from water wells has been brought under control and was therefore drastically reduced. The water needed for irrigation was brought to the site by a system of pipelines from a nearby dam.



Figure 3. Vineyards cultivated close to the wetland. (© Stefania D'Angelo)

a) Protecting wetlands and mitigating pressure/impact on wetlands

Twenty-one hectares of land in fragile and sensitive areas were acquired. Pressure from agriculture was reduced, both in terms of mechanical work (tillage) and quantities of chemical soil conditioners. In fact, a ban on herbicide use was implemented and the need for fertilizers was reduced because of decreased loss of fertile soil. Based on the results of studies on the biology of some species at the top of the food chain (umbrella species, e.g. the endemic pond turtle *Emys trinacris*), activities such as tillage and land clearing were regulated at specific times of the year, coinciding with the spawning stages of e.g. *Emys trinacris*. The above measures have had a positive cascading effect on many other species related to the aquatic environment.

b) Supporting rural livelihoods, equity, and social well-being

One of the most effective restoration actions in the area was the acquisition of all cultivated land very close to the lakes, which allowed the reduction of the impact on the lake ecosystems. The action was facilitated by the fact that these lands were difficult to be cultivated by the farmers. Lands purchased through the Management Body becomes a regional property.

Farmers are compensated for wildlife damage and supported to implement land improvements, crop rotations and other actions financed by the Common Agricultural Policy (CAP) of the European Union. Methods include establishment of grass rows, hedges at property boundaries, and dry stone walls. Farmers are regularly supplied with information on CAP funds through meetings and questionnaires. The ecological renaissance of the site, which has become a beautiful landscape area of great visual impact and rich in biodiversity, has prompted other companies (wineries, almond producers) to use the beauty of the area for sustainability branding of their products. Beauty and nature therefore are recognized by farmers and consumers as synonymous with quality.

c) Building resilience in people, communities, and ecosystems

Farmers have been involved in biodiversity assessment projects on their own lands (e.g. the WWF-Huawei project, see <https://www.prnewswire.com/in/news-releases/wwf-and-huawei-italy-launch-project-to-safeguard-biodiversity-in-italian-agroecosystems-301699015.html>), through comparison of biodiversity indicators between organic farms and conventional farms that use systemic pesticides. This project had a final phase of analysis of the results involving the entire agricultural sector, from technicians to farmers and users of the protected area. Meetings were organized with farmers on sustainable farming methods and on the ecosystem services related to different levels of water resources use and the presence of buffer strips.

d) Responsible and effective governance and institutions

The regional government, together with WWF, is working on a revision of the regional regulation for Nature Reserves and Parks, which in some cases was not strict enough (e.g. with respect to chemical weeding). The revision should include more integration and coordination with other land protection measures implemented by other authorities (such as the Regional Administration for landscape plan, Natura 2000 sites management plans and for the application of the National Action Plan for the sustainable use of pesticides according to UE Directive 128/2009/CE; Municipality of Mazara del Vallo for the municipal master plans; Superintendence for Cultural Heritage). This should result in better harmonization of the uses and constraints envisaged by the different planning tools. One important success factor in the good results obtained with the restoration of aquatic ecosystems is the continuous dialogue with farmers which leads to a better understanding of their difficulties and helps them to adopt more sustainable management systems. Another important element is the relationship of trust that has been created between farmers and the Managing Authority, through years of field work and regular contacts and meetings.

Conclusion

Rather than banning agriculture altogether, extensive agriculture within nature reserves should be supported to limit the abandonment of agriculture in protected areas. In fact, sustainable agriculture can support the biodiversity in a protected area, in terms of open areas, habitat mosaics, trophic resources for many species, and fire prevention. Funds are available to support farmers with protecting crops from pest species, such as wild boars, and with the introduction of sustainable agricultural practices that reduce impacts on ecosystems and maintains or increases ecosystem services. However, procedures for support and access to these funds should be streamlined. The use of pesticides and fertilizers should be limited as much as possible. Moreover, it is necessary to increase the suitable habitats for species linked to agroecosystems by maintaining or restoring the presence of grass cover, hedges, tree rows, and dry stone walls; and minimizing tillage. Through appropriate awareness raising, it is necessary to increase information and farmer support activities. Beauty and nature must be recognized by farmers and consumers as synonymous with product quality.

References

- d'Angelo S, Agapito Ludovici A, Canu A, Marcone F, Ottonello D (2020) Progetto di conservazione della testuggine palustre siciliana (*Emys trinacris*) nella Riserva Naturale Integrale “Lago Preola e Gorgi Tondi” (Mazara del Vallo, Sicilia occidentale). In: Ottonello D., Oneto F., Piccardo P., Salvidio S. (Eds), 2020. Atti II Congresso Nazionale Testuggini e Tartarughe (Albenga, 11-13 aprile 2019), 220 pp. Available at: https://wwfit.awsassets.panda.org/downloads/27_29_d_angelo_et_al_progetto_conservazione_emys_trinacris.pdf (in Italian)
- Ficetola GF, Salvidio S, D'Angelo S, Bonardi A, Bottoni L, et al. (2013) Conservation activities for European and Sicilian pond turtles (*Emys orbicularis* and *Emys trinacris*, respectively) in Italy. *Herpetology Notes* **6**, 127-133.
- Ottonello D, D'Angelo S, Marrone F, Oneto F, Spadola F, Zuffi MAL (2021) *Emys trinacris* Fritz, Fattizzo, Guicking, Tripepi, Pennisi, Lenk, Joger, and Wink 2005—Sicilian Pond Turtle, Testuggine Palustre Siciliana. *Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs* 112-1.
- Rondinini C, Battistoni A, Teofili C (compilers) (2022) Lista Rossa IUCN dei vertebrati italiani 2022 Comitato Italiano IUCN e Ministero dell'Ambiente e della Sicurezza Energetica, Roma
- WWF (nd) RNI Oasi WWF Lago Preola e Gorgi Tondi (The Integral Nature Reserve Lago Preola e Gorgi Tondi). WWF Italy, available at: <https://www.wwfsicilianordoccidentale.it/riserve/le-riserve/rno-lago-preola-e-gorgi-tondi/> (web page in Italian)

Case 11. Agrarian reform and environmental management to support farmers and protect the Sultan Marshes in Central Anatolia, Türkiye

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Site details

Item	Details
Site name	Sultan Marshes
Contracting Party/Country	Türkiye
GIS Coordinates	38°20'N 035°17'E
Site ID	661
RIS last updated	01.01.2008
RIS source	https://rsis Ramsar.org/ris/661?language=en
Surface area of case site (ha)	17,200 ha
Wetland type	Rivers, streams, floodplains; Lakes
Agricultural system type	Rainfed intensive; Irrigated

Main key message

The Sultan Marshes, once among the largest wetlands in the Northern Hemisphere, serve as a vital junction for two bird migration routes and offer crucial ecosystem services and products that sustain livelihoods. However, mounting pressures including population growth, water and land demand for agriculture, and pollution are increasingly straining this wetland habitat. Wetlands of International Importance should be prioritized for the implementation of agro-environmental schemes and can eventually act as lighthouses for the upscaling of sustainable practices.

The challenge presented by food production in relation to the Sultan Marshes

Sultan Marshes, also known as Sultan Sazlığı, is a vital wetland in Türkiye, renowned for its unique blend of freshwater and saline ecosystems. The wetland is located in Develi Basin, which is an area of about 100,000 ha (Dadaser-Celik, et al., 2009). This extensive area is characterized by large expanses of reeds and swamps, bordered by lush meadows and steppes (Figure 1). It serves as a critical stopover on the two principal migratory bird routes between Africa and Europe, offering refuge to a diverse array of avian species. From 2002 to 2004, botanical studies revealed a remarkable variety of 428 natural plant species within the marshes, 48 of which are endemic, showcasing the region's rich biodiversity. Bird surveys have recorded 301 species, reflecting the area's significance as a haven for birds, although these numbers may fluctuate due to seasonal and climatic changes (Yıldız, et al., 2023).



Figure 1. Meadows and reeds in Sultan Marshes National Park. (© Melike Kuş)

Historically, the marshes have faced challenges due to policies aimed at malaria prevention and the expansion of agricultural land from the 1950s to the 1970s. The construction of three irrigation dams on the rivers that feed the wetlands, coupled with the promotion of irrigated farming and cattle breeding, has led to a substantial increase in agricultural areas within the Sultansazlığı National Park, Wetland of International Importance (Figure 2). Consequently, this has resulted in a decrease in water surfaces and vegetated zones (Table 1). Moreover, the Sultan Marshes are currently grappling with environmental pressures such as pollution from agricultural, industrial, and residential sources, overgrazing, erosion, and the impacts of drought. These factors underscore the need for sustainable management practices to preserve this ecological treasure.



Figure 2. Agricultural land around Sultan Marshes National Park. (© Melike Kuş)

As a Ramsar-listed wetland, the Sultan Marshes are not only a testament to Türkiye's rich natural heritage but also a crucial site for conservation efforts. The marshes are accessible for observation and education, with facilities like a boardwalk and a viewing tower that allow visitors to experience the wetland's beauty and learn about its inhabitants.

In light of these challenges and the marshes' ecological importance, it is imperative to continue fostering conservation initiatives and develop sustainable agricultural practices to protect and sustain the Sultan Marshes for future generations.

Table 1. Land use and land cover changes in Sultansazlığı National Park and its immediate surroundings (1977-2014). Percentages are calculated on the basis of the basin border (Develi Plain, 104,852 ha).

	1997		2003		2014	
	Area (ha)	Perc. (%)	Area (ha)	Perc. (%)	Area (ha)	Perc. (%)
Water Surface	5314	5.1	2854	2.7	2100	2.0
Reeds and Marshes	4848	4.6	8775	8.5	10380	9.9
Unvegetated area	6726	6.4	9083	8.7	9079	8.7
Pasture (sparse vegetation)	28254	26.9	25473	24.3	26490	25.3
Pasture (heavy vegetation)	40197	38.4	31790	30.3	22354	21.3
Rainfed agriculture	17952	17.1	10943	10.4	6303	6.0
Irrigated agriculture	1561	1.5	15934	15.1	28146	26.8

Source: Sönmez & Somuncu (2016)

Actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

Excessive exploitation of groundwater and surface water sources, primarily from dam construction, profoundly impacts Sultan Marshes (Figure 3). Thus, efficient water management, including crop pattern management, is highly important in the area. Current crop production around the lake includes maize, sugar beet, fruit, and vegetables which all have high irrigation requirements. Rainfed agriculture and more efficient techniques in irrigated farming are promoted in the area in line with the Sultan Marshes National Park and Ramsar Site Management Plan (see next section). The farmers can apply for a 50% subsidy provided by the government for efficient irrigation systems. Increasing soil carbon content by enhancing soil water retention and preventing erosion is another strategy to reduce irrigation demands. Implementing conservation agriculture practices such as zero or reduced tillage, crop rotation, cover crops, green manure, etc. can achieve this goal.



Figure 3. Irrigated agriculture around Sultan Marshes National Park.
(© Melike Kuş)

In a study conducted for the detection of pesticides in Sultan Marshes (Peker, 2020), 48 different types of agricultural chemicals, including pesticides, insecticides, herbicides, acaricides, and fungicides, were detected. Sustainable practices, including Integrated Pest Management (IPM), organic farming, agroecological production, and biological control, can help to reduce pollution from agriculture. Currently, there are country-level agro-environmental subsidies provided by the government, from which the farmers in the region can benefit, such as Good Agricultural Practice Support, Organic Farming Support, and Biological and Biotechnical Control Support.

Animal husbandry is an important activity in the region; thus, the integration of crop and livestock production can be promoted. The manure can also be utilized for biogas and vermicompost production, which in turn can be used to improve the soil quality in agricultural fields. Overgrazing should be prevented by introducing holistic grazing practices in the pasture areas in the neighborhoods around the lake.

b) Protecting wetlands and mitigating pressure/impact on wetlands

Sultan Marshes has been designated as:

- Wildlife Conservation Area² in 1971 (45,000 hectares)
- Nature Reserve³ in 1988 (17,200 hectares)
- First Degree Natural Site⁴ in 1993
- Wetland of International Importance⁵ in 1994 (17,200 hectares)
- National Park⁶ in 2006 (24,523 hectares)
- Natural Site-Sensitive Area to be Strictly Protected⁷ in 2020

The "Sultan Marshes National Park and Ramsar Site Management Plan" was prepared within the scope of the "GEF II - Biological Diversity and Natural Resource Management Project" carried out under the coordination of the General Directorate of Nature Conservation and National Parks. The plan was targeted at reestablishing the ecological balance disrupted in the era, ensuring the sustainability of resource use, and intervening in the threats in a participatory way that involves all interest groups (Karaarslan, 2015).

However, due to the overuse of the water sources for irrigation in the area and drought, the total size of the wetland was reduced by almost 50% from 1977 to 2003 (Sönmez & Somuncu, 2016). Thus, the Wetland Commission took further precautions such as supplying the wetlands with water from the dams. In addition, more water was provided from the Zamantı River through an interbasin water transfer project completed in 2010 to irrigate additional land in the Develi Basin. This resulted in the expansion of the water surface in the wetland to its largest extent in the last 22 years (Karaarslan, 2015). However, the introduction of water from another basin raises concerns regarding the water quality, composition, and introduction of alien species.

² Areas that have wildlife values, where living environments are protected along with plant and animal species, and their continuity is ensured.

³ Areas important in terms of scientific studies and education, contain ecosystems and species that are rare, endangered, or about to disappear. These areas require absolute protection and are available only for scientific and educational purposes.

⁴ Areas of natural beauty that have scientifically extraordinary, universal value are designated as natural sites. Site areas are divided into urban sites, archaeological sites, historical sites, and natural sites.

⁵ These are wetlands that meet at least one of the criteria of the Convention on Wetlands and are declared as Wetlands of International Importance.

⁶ Pieces of nature scientifically and aesthetically rare nationally and internationally, have conservation, recreation, and tourism areas with natural and cultural resource values.

⁷ Land, water, and sea areas where the use of area and all impacts to the area are limited, where human entrance is prohibited when needed, and are protected by special measures taken for scientific research, education, or environmental monitoring purposes.

To estimate the ecosystem value of the area, a valuation study was conducted for the ecosystem services and biodiversity of the site (Bilgin, et al., 2012). The valuation study included food production, water provisioning, industrial goods and services, energy (organic manure and biogas), carbon and nitrogen sequestration and climate regulation, decomposition and detoxification, and pollination. The combined value of these ecosystem services was determined to be 801,503,578 USD⁸.

c) Supporting rural livelihoods, equity, and social well-being

Given their higher profitability, farmers favor irrigated crops when water is available. Moreover, the rising severity and frequency of drought events lead to increased irrigation needs, placing significant strain on water resources. There are agricultural lands in the northern and southern parts of the basin and a significant amount of the local population earns their income from agriculture. According to Karaarslan (2015), 57.7% of the local people own agricultural lands, and 66.1% are engaged in cattle and sheep breeding, which causes intense grazing pressure in the area. 18% of the population earns income only from reed cutting. The traditional production is regulated at the site and some incentives to support farmers' livelihoods are provided depending on the available budget (although the exact nature of regulations and incentives are not known because the management plan is not publicly available). For example, in the Anatolian Water Basins Rehabilitation Project conducted between 2004 and 2012, micro-irrigation equipment, fruit tree seedlings, seeds, fertilizers, and bee hives were donated to the farmers. Direct seeding machinery was also donated to some villages (ORAN, 2013).

As part of the Agrarian Reform Implementation Project (TRUP), the Environmentally Based Agricultural Land Protection (ÇATAK) Programme was launched to protect sensitive areas exposed to severe erosion, and Sultan Marshes was one of the pilot sites. The ÇATAK Project aims to protect the soil structure, vegetation, and water in the area (details are provided below).



Figure 4. Walking trail in Sultan Marshes National Park.
(© Melike Kuş)

To create new livelihood opportunities in the Wetland of International Importance, nature tourism activities such as photo safaris are organized and some local people are trained as guides in the tourist center. Local people are also employed in the National Park as security staff. Bird watching is an important activity for the local economy. There is an information center, an observation tower, and a

⁸ Converted from Turkish Lira to USD utilizing the mid-year exchange rate of 2012 (year of study) provided by the Central Bank of Türkiye.

walking trail for tourists visiting the site (Figure 4). Boats operated by local people take tourists and bird watchers into the marshes.

d) Building resilience in people, communities, and ecosystems

The Environmentally Based Agricultural Land Protection (ÇATAK) Programme was implemented in line with the communiqué No. 2016/9, in the agricultural areas around the Sultan Marshes, to ensure the protection of soil and water quality, the sustainability of renewable natural resources, the prevention of erosion, and the negative effects of agriculture. The program included three categories of subsidies based on some conservation practices such as minimum tillage (first category); terracing, mulching, fertilizing with barn or farm manure, green manuring, preventing overgrazing, cultivating perennial grasses or perennial legumes other than clover (second category); and integrated crop management, reduced use of fertilizers, efficient irrigation techniques, organic agriculture of good agricultural practices (third category). Boz et al. (2013) stated that the Programme was highly adopted and should be extended to other regions. Predominant practices employed in the area under the Programme encompassed using legume forage crops in rotation, mindful application of pesticides and chemical fertilizers, and employing efficient irrigation systems. The study also reported (without further explanation) that farmers who lease land rather than own it find it exceedingly challenging to embrace agro-environmental practices.

e) Responsible and effective governance and institutions

The majority of the Wetlands of International Importance land is owned by the State, while there are some lands within the area owned by local people. The site is governed by a management plan (see above). Four zones are determined in the management plan in line with the Regulation on the Protection of Wetlands: "Absolute Protection Zone, Sensitive Use Zone, Sustainable Use Zone, and Buffer Zone". In the Sustainable Use Zone, traditional natural resource use practices are permitted. In this particular zone of Sultan Marshes, there are the Planned Thatch Cutting Zone, the Water Resources Protection and Controlled Use Zone, the Controlled Agriculture Zone, the Controlled Grazing Zone, and the Visitor Reception Zone. There are two commissions (national and local), with the local commission (in which local authorities, academia and NGOs participate) meeting at least twice per year to discuss the issues and applications. Farming organizations are also invited to the meetings. The human activities in the area are regularly monitored via site visits by the Provincial Directorate of Nature Conservation and National Parks and meetings with the local stakeholders. Annual monitoring reports are prepared each year. To mobilize the participation of stakeholders and increase their willingness to participate in the management activities, study tours are organized to other similar areas and regions, materials introducing the field are prepared and shared with the stakeholders, and administrators frequently visit the field and deal with the problems of the field (Yenilmez-Arpa, 2011).

Conclusion

Irrigated crop production must align with the water needs of the lake ecosystem, necessitating basin-level planning to optimize crop irrigation and support farmer livelihoods. The ÇATAK programme that has been carried out in the country, including in the Sultan Marshes National Park region, is a successful model that promotes resource efficiency, improved natural resource management, and reduction of pollution and erosion. The program provided incentives to the farmers who applied the stated conservation agriculture practices, which created behavioral changes. In addition to the incentives, extension training should be provided to the producers as knowledge gaps might result in inefficient practices.

Effective stakeholder engagement is fundamental for the success of agro-environmental schemes in Wetlands of International Importance, where conservation measures intersect with agricultural livelihoods. It is possible to develop and implement sustainable agricultural practices that promote both ecological integrity and human well-being in these critical wetland ecosystems through the involvement of various stakeholders - government agencies, local communities, farmers, non-governmental organizations (NGOs), researchers, and businesses - in the decision-making processes. Furthermore, embracing diverse perspectives enables the integration of invaluable local knowledge into both conservation and agricultural management strategies.

References

- Bilgin A, Doğan M, Erpul G, Kandemir İ, Aksoy A, Karataş A (2012) Doğa Korumanın Ekonomik Sisteme Entegrasyonu Taslak Kılavuzu 2 (Integration of Nature Conservation into the Economic System Draft Guideline 2). Biyokıymetlendirme Teknik Uygulayıcıları: Sultan Sazlığı Milli Parkı Pilot Uygulaması (Biovaluation Technical Practitioners: Sultan Marshes National Park Pilot Application). Ankara: ORMAN VE SU İŞLERİ BAKANLIĞI (Ministry of Forest and Water Affairs).
- Boz İ, Şahin A, Paksoy M, Giray FH, Direk M (2013) Çevre Amaçlı Tarımsal Arazilerin Korunması Programı'nın (ÇATAK) Yayılması ve Benimsenmesi (Dissemination and Adoption of the The Environmentally-Based Agricultural Land Protection (ÇATAK) Programme). Kahramanmaraş. Retrieved from: <https://search.trdizin.gov.tr/tr/yayin/detay/613804>
- Dadaser-Celik F, Coggins JS, Brezonik PL, Stefan HG (2009) The projected costs and benefits of water diversion from and to the Sultan Marshes (Turkey). *Ecological Economics* **68**, 1496-1506.
- Karaarslan Z (2015) Sultan Sazlığının Sulak Alan Restorasyonu Uygulamaları Açısından Değerlendirilmesi (Evaluation of Sultan Marshes in Terms of Wetland Restoration Implementations). Master Thesis. Ankara University Graduate School of Natural and Applied Sciences Department of Landscape Architecture.
- ORAN (2013) TR72 Bölgesi Tarım Raporu (TR72 Region Agriculture Report). Kayseri. Orta Anadolu Kalkınma Ajansı (Central Anatolia Development Agency- ORAN). Retrieved from: <https://www.kalkinmakutuphanesi.gov.tr/dokuman/tr72-bolgesi-tarim-raporu/740>
- Peker B (2020) Sultan Sazlığında Pestisit Kirliliğinin Tespiti (Determination of Pesticide Pollution at Sultan Marshes). Master Thesis. Erciyes University, Graduate School of Natural and Applied Sciences.
- Sönmez ME, Somuncu M (2016) Evaluation of spatial change in the Sultan Marshes in terms of sustainability. *Türk Coğrafya Dergisi* **60**, 1-10. <http://dx.doi.org/10.17211/tcd.70341>
- Yenilmez-Arpa N (2011) Türkiye'de korunan alanların belirlenmesi, planlanması ve yönetimi sürecinde katılımcılığın değerlendirilmesi: Sultan Sazlığı Milli Parkı (Assessment of the participation process in the determination, planning and management of the protected areas in Türkiye). PhD Thesis. Landscape Architecture Department, Ankara University.
- Yıldız R, Yücel C, Katırcıoğlu G (2023) Korunan Alanların Sürdürülebilirliğinde Planlama ve Yönetim: Kayseri Sultan Sazlığı (Planning and Management in the Sustainability of Protected Areas: Kayseri Sultan Marshes). *Planlama* **33**, 324–339.

Case 12. The toMOORow PaludiAlliance – How Developing Value Chains for Paludiculture Products Can Help Creating Large-scale Wet Peat Landscapes

Compiler(s) details

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Site details

Item	Details
Site name	N/A
Contracting Party/Country	Germany
GIS Coordinates	N/A
Site ID	N/A
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	N/A
Wetland type	Peatlands
Agricultural system type	Rainfed extensive; Livestock (extensive)

Main key message

The joint project toMOORow PaludiAlliance aims to contribute to the rewetting of drained peatland sites with a focus on Germany. To this end, an alliance of commercial enterprises has been formed, the so-called “Alliance of Pioneers”. This alliance is developing scalable value chains for paludiculture products in various sectors, thereby creating demand for paludiculture biomass. This, in turn, is a necessity for the transformation of peatland farming.

The challenge presented by peatlands used for agriculture

There are around 1.8 million hectares of peatlands in Germany - mainly in the north and south of the country. Around 95% of these peatlands are currently drained - in other words, they are no longer intact peatlands. Much of this area is drained for agricultural and forestry use, totalling around 1.3 million hectares. Drained peatlands are responsible for 7.5% of Germany's greenhouse gas emissions. This corresponds to approx. 53 million tonnes of CO₂ equivalents per year. To meet the German government's climate targets, approximately 50,000 hectares of drained peatland would have to be rewetted every year. Currently, only about 2,000 hectares are being rewetted.

To meet this challenge, the German government - in particular the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection and the Federal Ministry

of Food and Agriculture - has launched or announced various funding programmes. To date, peatlands that have been drained for agricultural use have mostly been lost as production sites for agriculture after being rewetted. However, it is evident that comprehensive, socially acceptable and accepted peatland protection can only succeed if peatland restoration, productive agriculture and forestry, and climate-protecting and biodiversity-promoting methods of use are harmonised. The willingness of farmers to rewet the peatlands they manage presupposes that they recognise the long-term demand and income potential of biomass like reed, cattail, sedge, reed canary grass, peat mosses or other wet meadow grasses.



Figure 1. Cattail harvest
(© Tobias Dahms)

The toMOORow Initiative was founded in 2021 by the Michael Otto Environmental Foundation (MOEF) and the Michael Succow Foundation (MSF), partner in the Greifswald Mire Centre (GMC). The PaludiAlliance is a joint project funded by the Agency for Renewable Resources (FNR) on behalf of the German Federal Ministry of Food and Agriculture, and run by MOEF, MSF, and the University of Greifswald (UG). The goal of the toMOORow Initiative and PaludiAlliance partners is the development of scalable value chains for biomass from paludiculture. For this project, 14 industry-leading companies have been acquired and have joined forces in an “Alliance of Pioneers”. The companies that have joined this demand alliance have committed themselves in a joint declaration of principles to launch paludiculture pilot projects in their own companies from 2024, and to introduce paludiculture biomass into their value chains. The overarching goal of the alliance is to secure farmers' incomes and thus generate a willingness to contribute to peatland climate protection through demand for paludiculture biomass as a raw material. This is to be achieved by converting the current processes for manufacturing proven products to include a proportion of raw materials from paludiculture biomass with corresponding scalability within the company - with an impact on the entire industry.

Analysis of actions or opportunities for actions to make the system more sustainable

Before the start of the joint project, a feasibility study was commissioned to identify sectors with high potential and to recruit pioneering companies such as OTTO, PreZero, Procter & Gamble and Strabag as active supporters. The feasibility study, carried out by Systain Consulting with the support of the Research Institute of Organic Agriculture (FiBL) as part of the toMOORow initiative, identifies scalable utilisation options and value chains for biomass from paludiculture. The study is based on 42 interviews with companies, research institutions, associations and other organizations as well as accompanying research. In principle, there is promising potential in various sectors and applications.

Both general raw material and demand trends as well as current political guidelines and regulations make Paludi-biomass generally attractive as a raw material of the future. Some examples of applications are (see also Figure 2):

Paper and cardboard packaging, incl. fibre castings: The trend towards using annual plants as a cellulose raw material as an alternative to wood can be used here. With a calculated share of 5% Paludi-biomass in the amount of fresh fibre, 10% of the nationwide rewetting potential of agriculturally used peatland areas could be covered.

Building and insulation materials: Materials from paludicultures such as cattail or reed have advantageous raw material properties, including thermal conductivity, mould resistance, moisture regulation and flammability. With a calculated share of 5% Paludi-biomass in the insulation market, 12% of the nationwide rewetting potential of agriculturally utilised peatland areas could be covered.

Wood-based materials and furniture: Possible initial areas of application include individual items of decorative furniture and construction panels in the interior design sector, such as interior door panels. With a calculated quantity share of 5% Paludi-biomass in wood-based materials, 4% of the nationwide rewetting potential of agriculturally utilised peatland areas could be covered.

Plastics and chemical base materials: Paludi biomass can be an alternative to fossil raw materials for plastics and base materials for varnishes, paints, adhesives and the like. With a 2% share of Paludi-biomass as a raw material in plastics, 5% of the nationwide rewetting potential of agriculturally utilised peatland areas could be covered.



Figure 2. a) Prototype inner door panel made from paludiculture biomass. (© Baufritz)



b) One of 100,000 test shipping cartons made from 10% paludiculture biomass. (© OTTO)

Other possible applications include bioenergy, dry granulates (e.g. cat litter) and substrate constituents for horticulture. The study calculates a total requirement of 1,572,000 tonnes of Paludi-biomass per year for all material uses considered, with a conservative admixture of 5%, and thus an area potential of 314,000 hectares of rewetted peatland. This is around one third of the total area potential (1 million hectares) of peatland in Germany that could be rewetted.

The PaludiAlliance project pursues the following specific objectives during the 34-month project period (2024-2026):

1. Knowledge transfer for the demand side: Preparation and provision of information in interaction with the partners within and outside the PaludiAlliance
2. Successful implementation of paludiculture biomass in existing value chains of different utilization options
3. Establishment, organization and strategic development of the PaludiAlliance
4. Biomass supply from agriculture through network development and establishment of a digital “paludiculture biomass exchange”
5. Biomass quality and processing and product development: Determination and assurance of the raw material quality of different biomass and support in optimizing its processing for different areas of application

In line with their individual expertise, the toMOORow PaludiAlliance partners will advise and support the companies in piloting innovative uses and product developments from paludiculture biomass, integrate them into existing and newly established networks and provide them with organisational and technical support during this transformation process.

It is challenging to describe this case in terms of the FAO Principles and Actions for Sustainable Agriculture because this case is more about product development, processing and marketing than about paludiculture itself. Paludiculture in general addresses Principles a) (Options for increasing resource use efficiency) and b) (Protecting wetlands and mitigating pressure/impact on wetlands) by allowing peatlands to remain wet and thus protecting the landscape and climate functions and biodiversity of these wetlands. The toMOORow partnership and PaludiAlliance project, however, focus much more on Principles c) (Supporting rural livelihoods, equity, and social well-being) and e) (Responsible and effective governance and institutions), by supporting farmers through creating a demand and developing a value chain for the products from paludiculture and by bringing together a broad partnership of societal actors with different roles, from research for product and market development to active business engagement. Ultimately, these joint efforts also contribute to Principle d) (Building resilience in people, communities, and ecosystems).

Conclusion

The toMOORow PaludiAlliance enables connections between the supply side (agriculture) and the demand side (industry) for renewable raw materials from wet peatlands and knowledge transfer between the relevant companies and the actors of many other funded paludiculture projects in Germany. Through overarching scientific work, a gain in knowledge that goes beyond individual projects and a faster and more comprehensive transfer of knowledge into practice are achieved.

The PaludiAlliance works closely with the model and demonstration projects (‘MuD projects’) funded by the German Federal Ministry of Food and Agriculture on the topic of ‘peatland protection including the use of renewable raw materials from paludiculture’ and the pilot projects (‘peatland pilots’) funded by the German Federal Ministry of the Environment and Consumer Protection. This includes, in particular, the preferential use of paludiculture biomass for the pilot projects and tests from the project and research areas.

To consolidate the intended results of the three-year project period, further development of the PaludiAlliance into an independent legal entity is planned, which should ensure a long-term organisational framework to permanently guarantee the following services:

- Coordinating and advising the stakeholders involved along the entire value chain (agriculture and business)

- Expansion of the economic utilisation of paludiculture and thus the demand for raw materials/production volume in agriculture
- Tapping into innovative institutions and networks to accelerate the process

References

Website (German): www.tomoorow.org

Feasibility study (German): https://cdn.prod.website-files.com/613201573773233e276a02b9/652cfbc1da987ccd91429a42_toMOORow_Systain_Machbarkeitsstudie.pdf

Case 13. The Xochimilco peri-urban wetland: a resilient agro-ecosystem of biocultural importance

Compilers details

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Site details

Item	Details
Site name	Sistema Lacustre Ejidos de Xochimilco y San Gregorio Atlapulco (here referred to as <i>Xochimilco peri-urban wetland</i>)
Contracting Party/Country	Mexico
GIS Coordinates	19°16'N 99°04'W
Site ID	1363
RIS last updated	2004
RIS source	https://rsis Ramsar.org/RISapp/files/RISrep/MX1363RIS.pdf
Surface area of case site (ha)	2,657 ha
Wetland type	Rivers, streams, floodplains; Agricultural wetlands
Agricultural system type	Irrigated; Rainfed extensive, intensive; Livestock extensive, intensive; Horticulture

Main key message

Managed since pre-Columbian times for agricultural production, nowadays the Xochimilco agro-ecosystem faces significant challenges. Actions towards more just and sustainable agroecological pathways entail community-based initiatives in which local actors lead processes to share knowledges and practices associated to its biocultural heritage, and co-produce context-dependent strategies for self-management and empowerment.

Challenges presented by food production in the Xochimilco wetland

The peri-urban wetland of Xochimilco in Mexico City is one of the last remnants of the Basin of Mexico's original lake system. The “Sistema Lacustre Ejidos de Xochimilco y San Gregorio Atlapulco” (as it is officially called) consists of “chinampas” surrounded by canals. Chinampas are rectangular crop plots that have existed since pre-Columbian times and serve as the agricultural production units of the system (Figure 1). Currently the surface area of the wetland is 2,657 ha but originally the chinampa system was much larger. Besides the richness in cultural heritage values, the wetland is also ecologically important as habitat for the endemic axolotl (*Ambystoma mexicanum*). This living

biocultural heritage site still contributes to the food security of Mexico City, with a population of over 9 million, within a megacity of more than 22 million inhabitants, and sustains other key ecosystem components and services such as groundwater provisioning, as well as climate and hydraulic regulation.



Figure 1. Xochimilco peri-urban wetland, Mexico City with a view from the wetland of the surrounding mountains in the Basin of Mexico (left); and a chinampa (right). (© M. Mazari-Hiriart)

Despite these benefits, the wetland faces significant challenges, such as the unsustainable extraction of groundwater to supply drinking water to the city. This is an important cause for the decrease in the water table, affecting in turn the canal network and contributing to the decline of the chinampa agro-ecosystem. Since 1957, the wetland has been recharged with treated wastewater (instead of spring water) of poor quality (high loads of nutrients and microorganisms) and distributed unequally (prioritizing the tourist area where the *trajineras* tourist boats operate), but being the main source of water for the wetland, key to its survival. This historical tension, referred to as the city's "debt" to the chinampa zone for having drained the springs that used to feed the canals over time, has not been resolved and is at the root of a sense of indignation, inequity and dispossession among the local inhabitants and farmers -or *chinamperos*- of Xochimilco.



Figure 2. Marigolds (Cempuasuchil) planted for the Day of the Death Mexican tradition. (© M. Mazari-Hiriart)

Originally, the chinampas were efficient sub-irrigation systems that allowed three to five crops per year, operated as integrated agricultural systems by native families, using farming techniques that were compatible with and shaped the ecological character of the wetland. Currently, the chinampas are in varying degrees of transition towards more intensive agriculture with high fertilizer and

pesticide inputs (notably horticulture, including vegetables and ornamental plants such as marigolds for the "Day of the Dead" festivities and poinsettias for Christmas; Figure 2). Chinampa plots are also converted from agriculture to housing or leased for social events such as weddings, as football pitches, and for agro-tourism or eco-tourism. This land use change occurs as a result of several factors, including the abandonment of traditional farming practices and the ease with which land can be urbanized, even illegally.

In summary, agricultural abandonment is mainly associated with the following drivers:

- a) Small-scale agriculture has been neglected for decades and most commercial and government incentives in Mexico have mainly favoured its intensification or subsumption by the industrial food system. This is exacerbated by the significant loss of intergenerational transmission of knowledge related to agroecological practices and cultural heritage values (mostly due to portraying the image of a farmer with despire and associated with poverty and lack of education, and the increasing number of young people that seek an urban life);
- b) Environmental degradation (including poor water quality and insufficient water quantity, exacerbated by climate change and unsustainable water extraction for the city) affects the profitability of farming in the chinampas (Figure 3). Small-scale farmers also struggle with insufficient fair and steady market opportunities, in contrast with intensive farming areas that supply the city through large centralized markets. This has led many local families to diversify their economic activities into e.g. commerce and tourism services, and not dedicate all of their time to farming;
- c) Housing needs, combined with land tenure irregularities, corruption, and authorities' "blindness" that favour the conversion of land from agriculture into housing. Those involved in conversion to housing urbanize are usually farmers who use one of their chinampas to build their houses (even when this poses a tension with their farming tradition), as well as people from other areas of the city with housing needs, or small-scale farmers who come from other states in search of better wages.



Figure 3. Insufficient water of poor quality is supplied to the canals from water treatment plants by the Mexico City Water System authority (SACMEX); Informal settlements with varying degrees of consolidation present within the conservation area polygons. (© P. Pérez-Belmont, San Gregorio Atlapulco, 2019)

a) Options for increasing resource use efficiency

Farming in the chinampas is based on efficient resource management (e.g., water sub-irrigation through the canals and soil, the use of mud beds as seed beds, crop rotation, and the use of local plant varieties). However, these practices have been gradually lost due to the challenges faced within the wetland. Recovering these agroecological techniques and incorporating other regenerative agriculture approaches offers opportunities not only to promote efficient resource use through the restoration of soils or the re-establishment of nutrient cycles, but also, and importantly, to rescue the knowledge, identity, and traditions for food production in the *chinampera* culture (Figure 4). Restoring the traditional practices also answers to economic needs, as it is based on a social and solidarity economy approach; and involves enabling decentralized governance schemes to protect territories, seeds, biodiversity, and water. Improving water availability and its quality for agriculture entails: a) treatment of the water discharged from surrounding informal settlements, as well as addressing inefficiencies in the city's wastewater treatment plants that discharge treated water into the wetland; and b) scaling up of ecotechnologies for rainwater harvesting and storage.



Figure 4. Agroecological farming (left) vs. farming with agrochemicals and plastics (right).
(© P. Pérez-Belmont, 2019)

b) Protecting wetlands and mitigating pressure/impact on wetlands

Xochimilco wetland has unique ecological and cultural values that have led to various formal protection initiatives. The wetland has been a UNESCO World Heritage site since 1987, a Wetland of International Importance since 2004, and a FAO Globally Important Agricultural Heritage System (GIAHS or SIPAM in Spanish) since 2017. Also, it has been a federal Natural Protected Area since 1992 and typified as Conservation Land through a state policy in 2012. The effectiveness of these formal designations is contested (see below under governance and institutions). In addition to these formal conservation programs, diverse projects seek the restoration and conservation of the wetland through the recovery of the cultivation in the chinampas and the wise use of resources. Research projects of different universities focus on agroecology and food sovereignty. For example, the Chinampa-Refugio (*Chinampa-Refuge*) project (coordinated by the Institute of Biology, UNAM) supports producers to maintain the canals and treat their waters to provide suitable water quality conditions for axolotls (*Ambystoma mexicanum*, an endangered salamander species endemic to the wetland), which in turn contributes to protecting other species of ecological importance in the wetland. Associated with this is the ecological labelling for wetland produce such as the “Etiqueta Chinampera” project which

guarantees that production in the areas converted to chinampas-refugios is developed with sustainable agroecological practices.

c) Supporting rural livelihoods, equity, and social well-being

The Mexico City Ministry of the Environment (SEDEMA) and the Commission for Natural Resources and Rural Development (CORENADR) implement programs to conserve, improve, protect, and safeguard ecosystems and their associated productive and biocultural aspects across conservation areas in the city. For instance, programs such as “Atépetl Bienestar”, the House of Seeds and the Green Seal for Agricultural Production in Conservation Land promote agro-ecological practices with mechanisms for community environmental monitoring and compensation for the maintenance of ecosystem services. The governmental Inter-Institutional Program of Specialisation in Food Sovereignty and Strategic Local Advocacy Management (PIES ÁGILES) created learning communities operating locally. Also, schools for *chinamperos* (Escuelas Chinamperas) have been created in collaboration with other non-governmental organizations (both for-profit and non-profit) to bring together indigenous local knowledge with science and technology for promoting an agroecological transition. The increase in alternative food networks, which sell vegetables directly to consumers homes, city organic markets, or certain restaurants across the city, has favoured the market for food produced in the chinampas. However, the economic impact on farmers has been limited as this form of commercialization depends on consumers willing to pay a higher price for these products. There are also initiatives promoted by groups of organized *chinamperos* (e.g. Chinampayolo) that seek fair-local trade mechanisms for agroecological produce.

d) Building resilience in people, communities, and ecosystems

Based on the *Seven principles for building resilience in social-ecological systems* (Biggs et al., 2015), the following actions might contribute to enhancing resilience in Xochimilco:

- *Maintain diversity and redundancy*: support and strengthen local initiatives, collectives, and projects that support agrobiodiversity practices (e.g. Chinampayolo, Granja Apampilco, Olintlalli, Colectivo Ahuejote, IAX) and the protection and sovereignty of seeds (e.g. LUM K’INAL).
- *Manage connectivity*: facilitate the connection of existing networks of producers to collectives that aim at protecting a particular ancestral territory (e.g. Asamblea General Permanente San Gregorio Atlapulco; https://x.com/asamb_atlapulco), and to seed exchange networks to understand and make visible their needs and interests. Many of these groups require financial support, training in communication skills to make their projects visible, and spaces for knowledge exchange and for connecting to market opportunities.
- *Manage slow variables and feedbacks*: finance programs that support farming (particularly by young farmers) and create outreach strategies that communicate the importance of farming to revalue agriculture. Implement strategies to avoid land use change for urbanization in the chinampas, while creating markets for value-added agroecological products (as supply currently exceeds demand).
- *Encourage learning*: many local actors feel distrust, weariness, and discontent about outsiders who seek to implement projects in the wetland. Coherent and non-extractivist forms of collaboration are needed to form alliances that tackle the needs of communities and enable mutual learning. The facilitation of processes for deeper forms of dialogue is crucial to avoid further eroding of the relations between actors.
- *Promote polycentric governance systems*: Several instruments and institutions are involved in the management of the wetland (international - UNESCO, RAMSAR, FAO; national - CORENADR, DANPAVA, SEDEMA), but their roles and activities are not always clear. CORENADR provides programs that support producers but faces operational challenges. There is a need for coordination

(ensuring transparency in how social actors are involved and how resources are used) between these institutions, and with the local governance mechanisms.

e) Responsible and effective governance and institutions

The international and national policy instruments for the protection of the Xochimilco wetland lack coordination and effective implementation for several reasons: different boundaries or polygon areas are included in each protection instrument, resulting in mismatches that hinder coordinating actions among government institutions; lack of multi-level governance mechanisms to overcome the overlaps and voids in institutional mandates and responsibilities; as most instruments are not binding, strategies are not coherently articulated with national regulations and thus lack monitoring and evaluation; national instruments, although binding, lack mechanisms for the enforcement and compliance of regulations; dynamics of clientelism and corruption, mainly within the local government, favour and normalize informal urbanization; insufficient capacity for the surveillance and control of the informal and illegal settlement expansion.

Many inhabitants that belong to local communities or organized groups have alternative governance arrangements to address certain problems (e.g., when there is water shortage), some derived from their own customs and traditions (*usos y costumbres*). Other groups organize to receive support from government programs, but historically there is a widespread sense of distrust in government institutions. A fundamental challenge is to implement iterative and collaborative processes to thoroughly examine existing regulations, policies and programmes, and create mechanisms that recognize the differences between areas and communities that inhabit the wetland, and, unlike current regulations, address the needs and interests of the social actors involved, especially local inhabitants historically marginalized. However, as the interests and needs of the different individuals and groups are highly diverse, and often in conflict, developing strategies for representing plurality inherently entails the complexity of engaging with the underlying structural conditions that perpetuate marginalization and inequity.

Conclusion

Although most widespread narratives coincide on envisioned general actions to tackle the wetland social-ecological degradation, these fail to acknowledge a profound and silenced story: the struggles faced by Xochimilco wetland farmers and inhabitants throughout time for defending and protecting their ancestral territories against social-political dynamics centred in a neoliberal rationale that objectifies nature (i.e., as services, as external or separated from humans). This clash in paradigms is a core reason for the many unsuccessful efforts designed from outside. Understanding and respecting the different cosmovisions of the original communities (i.e., *Pueblos Originarios*) that inhabit the area, and how these shape their sense of identity and place attachment, is paramount for sustainably managing these types of agro-ecosystems with biocultural significance. Thus, no particular action or set of actions can contribute to achieving more sustainable futures if these do not emerge directly from the people that inhabit and experience on a daily basis the structural and systemic entrenched barriers that hinder their agency capacity. In agreement with the Convention on Wetlands *Resolution XIII.19 on Sustainable agriculture in wetlands*, addressing the numerous challenges mainly entails enabling community-based collaborative processes led by farmers and local actors through which self-management sustainable agro-tourism strategies are co-produced.

References

- FAO (2017) Chinampas Agricultural System in Mexico City. Globally Important Agricultural Heritage Systems (GIAHS). <https://www.fao.org/giahs/giahsaroundtheworld/mexico-chinampas-agricultural-system/en>
- Figuerola F, Puente-Urbe MB, Arteaga-Ledesma D, Espinosa-García AC, Tapia-Palacios MA, et al. (2022) Integrating agroecological food production, ecological restoration, peasants' wellbeing, and agri-food biocultural heritage in Xochimilco, Mexico City. *Sustainability* **14**, 9641. <https://doi.org/10.3390/su14159641>
- Guibrunet L, Rubio M, Flores Abreu IN (2023) Reclaiming traditional food systems in alternative food networks. Insights from Mexico City peri-urban agriculture. *Local Environment* **28**, 1153-1172. <https://doi.org/10.1080/13549839.2023.2194618>
- Eakin H, Charli-Joseph L, Shelton R, Ruizpalacios B, Manuel-Navarrete D, Siqueiros-García JM (2021) Wetlands under pressure: the experience of the Xochimilco T-Lab, Mexico. In: *Transformative Pathways to Sustainability* (pp. 138-153). Routledge.
- Jiménez M, Pérez-Belmont P, Schewenius M, Lerner A, Mazari-Hiriart M (2020) Assessing the historical adaptive cycles of an urban social-ecological system and its potential future resilience: the case of Xochimilco, Mexico City. *Regional Environmental Change* **20**, 7. <https://doi.org/10.1007/s10113-020-01587-9>
- Pérez-Belmont P, Lerner AM, Mazari-Hiriart M, Valiente E (2021) The survival of agriculture on the edge: Perceptions of push and pull factors for the persistence of the ancient chinampas of Xochimilco, Mexico City. *Journal of Rural Studies* **86**, 452-462. <https://doi.org/10.1016/J.JRURSTUD.2021.07.018>
- Sánchez González C (2024) Amenazas a la zona chinampera de Xochimilco: una investigación participativa utilizando cartografía social como herramienta. Universidad Nacional Autónoma de México. Facultad de Ciencias. http://132.248.9.195/ptd2024/ene_mar/0852299/Index.html
- Biggs R, Schlüter M, Schoon ML (Eds.) (2015) Principles for building resilience: sustaining ecosystem services in social-ecological systems. Cambridge University Press, UK.

Case 14. Restoration of pasture in a high-altitude protected wetland area (*bofedal*) in Peru

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Site details

Item	Details
Site name	Peru, Ancash region, Huari province, Chavín de Huantar district, Shirapata village - https://mountain.pe/proyectos/investigacion/restauracion-de-humedales-alto-andinos/
Contracting Party/Country	Peru
GIS Coordinates	9°41'21.80" S, 77°14'18.40" W
Site ID	N/A
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	0.4 ha, part of the 340,000 ha Huascarán National Park
Wetland type	Peatlands
Agricultural system type	Livestock extensive

Main key message

This case study highlights the hydrological restoration of a high-altitude wetland (*bofedal*) in Huascarán National Park, Peru. By installing containment dams, the project reversed drainage impacts, improved water storage, and supported local agriculture through better irrigation, illustrating alternative wetland-agriculture interactions.

The challenge presented by livestock development in relation to high-altitude wetlands

High-altitude wetlands in the Andes, like the *bofedales* of Huascarán National Park in Peru (Figure 1), are crucial for biodiversity and water regulation but face pressures from climate change and changing agricultural practices. *Bofedales* are a type of high-altitude wetland often classified as peatlands, characterized by the presence of cushion plants (of the families *Juncaceae*, *Asteraceae* and *Plantaginaceae*). Most wetlands in the National Park occur between 4,000 and 4,700 m above sea level, and occupy about 10% of the total National Park area. Peatlands occupy 6.3% of the Park area. About 50% of the wetlands are peatlands with a history of 12,000 years and peat layers deeper than 10 m (Chimner et al. 2019). *Bofedales* have been managed by indigenous agro-pastoral communities for centuries by diverting riverine water to irrigate valleys to expand the grazing areas for their alpaca

and llama herds (Lane 2014; Verzijl and Guerrero Quispe 2013; Young et al. 2023). Over the years, *bofedales* have also served as sources of water for lower-lying areas for irrigation and drinking water supplies to downstream cities. Some of these wetlands were drained to expand grazing lands for sheep and cattle, disrupting their ecology and reducing their capacity to provide other ecosystem services. These peatlands, managed by the Shirapata community, had been subject to such drainage for over a decade.

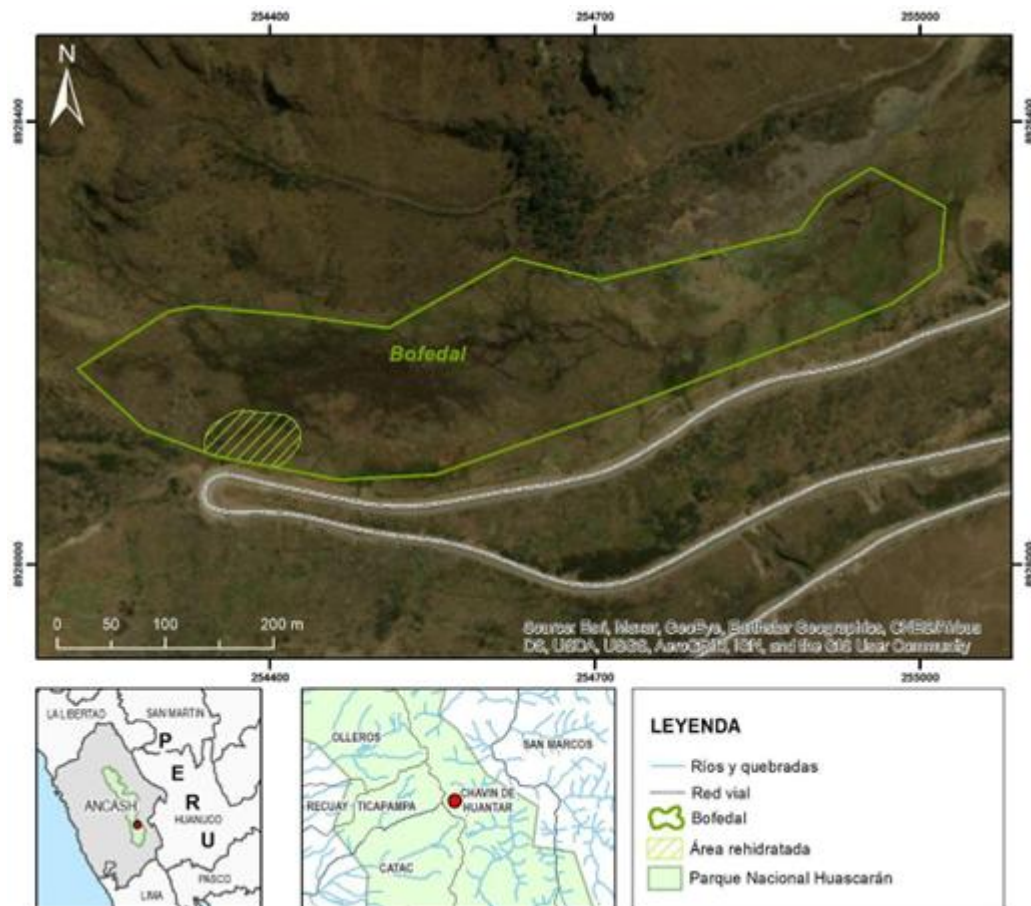


Figure 1. Location map of the restored peatland area (source: Elaborated by Daniella Vargas; baseline image: ESRI Maxar).

The wetland originally had a high number of endemic plants, bird, fish, amphibian and insect species, and the characteristic cushion plants can grow both on peatland and minerotrophic wet meadows (Chimner et al. 2020). The draining process undertaken in the past altered the hydrological regime by lowering the water table which caused a shift in dominant plant communities from native wetland species to more drought-tolerant grasses. The change in the water table level also threatened the wetland's biodiversity, carbon storage capability, and water retention capacity. Local livelihoods, dependent on grazing and agriculture, were also at risk as the degradation of the wetlands reduced water availability and pasture quality.

Direct drivers of this change included the impacts of climate change (reductions in water inputs because of glacier melt, reduced rainfall, and higher temperature), higher demand from other water users such as towns, farms and mines, population growth of both humans and grazing animals, and the introduction of sheep and cattle (Yager et al. 2021). Indirect drivers included socio-economic factors such as migration to cities and changes in the traditional governance mechanisms to protect these ecosystems. The market dynamics did not favour sustainable practices, as immediate economic

benefits from expanded grazing often overshadowed long-term ecological consequences (Yager et al. 2021).

The restoration initiative aimed to address some of these challenges by rewetting the peatland and restoring the higher water table level, restoring native vegetation, and providing alternative livelihoods through improved irrigation systems for agriculture. This approach required collaboration between local communities, scientific experts, and government agencies.

Analysis of actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

The installation of 22 canal blocks (Figure 2) increased water retention in the peatland, improving water availability for downstream irrigation. This intervention raised the water table significantly, from -69.4 cm to -38.0 cm in the dry season (with respect to the surface). Improved irrigation infrastructure allowed for more efficient water use in local agriculture, reducing the need to overexploit peatland resources.



Figure 2.
Installation of
dams to restore
a peat bog
(bofedal) in the
Pucavado
ravine,
Huascarán
National Park.
(© Beatriz
Fuentealba)

b) Protecting wetlands and mitigating pressure/impact on wetlands

The canal blocks mitigated the impact of previous drainage efforts, helping to restore the natural hydrological regime. The restored high water table reduces aerobic peat decomposition preventing degradation of the peat soil, therefore restoring the structure of the peatland. Also, monitoring showed partial recovery of native vegetation, such as *Carex cf. ecuadorica*, crucial for maintaining biodiversity in the *bofedales* peatlands. The return of native peatland vegetation also supports the continued accumulation of peat soil and supports habitat for local wildlife.

c) Supporting rural livelihoods, equity and social well-being

The National Park is surrounded by some 30 agro-pastoral communities that were herding livestock (mostly cattle and sheep) in the area even before the establishment of the park. The project supported the Shirapata community in adopting alternative livelihoods through better irrigation systems, reducing their dependence on grazing in the peatland. Local stakeholders, including farmers and municipal authorities, were actively involved in planning and implementing the restoration activities (Figure 3). At the landscape level, the restoration of the peatland has allowed the development and improvement of an irrigation system that benefits efforts of cropping or other alternative livelihood options outside the national park.

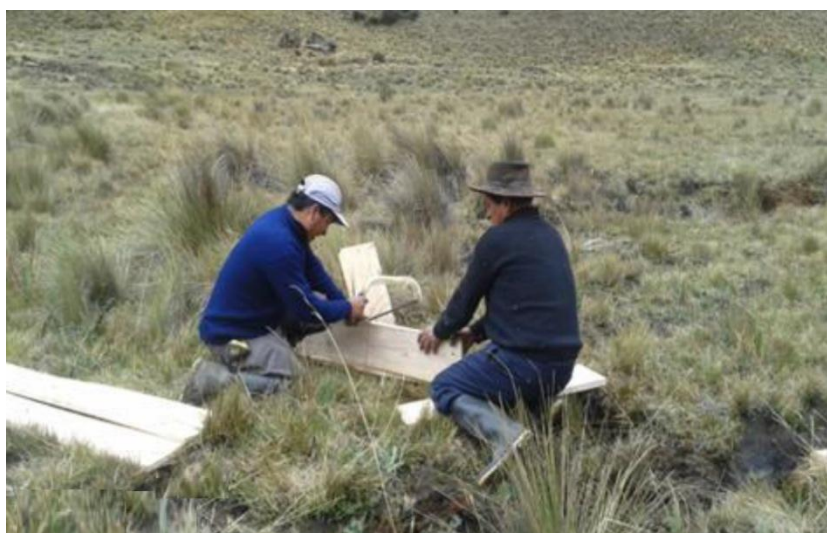


Figure 3. Local residents building the newly installed barriers. (© Mayra Mejía)

d) Building resilience in people, communities and ecosystems

The project provided technical training and financial resources for the installation of dams and irrigation systems, enhancing the community's capacity to manage their natural resources sustainably. By restoring the peatland, the project enhanced its role in carbon storage, contributing to climate mitigation efforts. The peatland rewetting also resulted in reductions in the CO₂ emissions from peat decomposition (Chimner et al. 2023). Enhanced water availability and new agricultural opportunities improved local livelihoods and resilience against environmental stressors including drought and flooding.

e) Responsible and effective governance and institutions

The Huascarán National Park was established in 1975, was designated a UNESCO Biosphere Reserve in 1977 and has also been a UNESCO World Heritage site since 1985 (Chimner et al. 2020). The restoration project involved multiple actors, including the Instituto de Montaña (a not-for-profit, non-governmental conservation and advocacy organization in Peru), Michigan Technological University (USA), local government, and the US Forest Service, ensuring a coordinated approach to restoration. The restoration efforts aligned with national policies on wetland management and climate change, providing a framework for sustainable practices. More generally, different modalities of governance arrangements between the national park authorities and the many surrounding communities have emerged, depending on resource use history and dependency, with varying outcomes in terms of community participation and perceived benefits (Rasmussen et al. 2019).

Conclusion

The restoration of the *bofedales* peatlands included blocking drainage canals to reduce drainage and erosion, reverting to a more natural hydrological regime. This resulted in an increase in the ground water level which benefited native plants, promoted soil carbon storage, and reversed the negative trajectory of land degradation and peat loss. The restoration efforts also improved water storage capacity, enabling the irrigation of downstream agricultural feedstock systems to reduce grazing pressures on the sensitive *bofedal* ecosystem. Blocking the drainage canals to enhance water storage also improved resilience of the Shirapata communities to climate change impacts such as prolonged periods of drought or more frequent and intense rainfall events. Coordination among stakeholders ensured improved land management and governance of the system while contributing to national climate policies. The combined actions of the project enhanced the sustainability of the ecological system by shifting away from extractive grazing practices toward agricultural systems that rely on functioning *bofedales* ecosystems. Nevertheless, the effects of climate change and changing socio-economic conditions prevent a return to the traditional sustainable management of the *bofedal* systems, and finding pathways to new forms of sustainability will remain a challenge for the surrounding communities and the authorities of Huascarán National Park.

References

- Chimner R, Bourgeau-Chavez L, Grelik S, Hribljan J, Planas A, et al. (2019) Mapping mountain peatlands and wet meadows using multi-date, multi-sensor remote sensing in the Cordillera Blanca, Peru. *Wetlands* **39**, 1-11. doi: 10.1007/s13157-019-01134-1.
- Chimner RA, Boone R, Bowser G, Bourgeau-Chavez LL, Fuentealba BD, et al. (2020) Andes, bofedales, and the communities of Huascarán National Park, Peru. *Wetland Science and Practice*, October 2020, 246-254.
- Chimner RA, Resh SC, Hribljan JA, Battaglia M, Bourgeau-Chavez L, et al. (2023) Mountain wetland soil carbon stocks of Huascarán National Park, Peru. *Frontiers in Plant Science* **14**, 1048609.
- Lane K (2014) Water technology in the Andes. Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures. DOI 10.1007/978-94-007-3934-5_10182-1
- Rasmussen MB, French A, Conlon S (2019) Conservation conjunctures: contestation and situated consent in Peru's Huascarán National Park. *Conservation and Society* **17**, 1-14.
- Verzija A, Guerrero Quispe S (2013) The System Nobody Sees: Irrigated Wetland Management and Alpaca Herding in the Peruvian Andes. *Mountain Research and Development* **33**, 280-293. <https://doi.org/10.1659/MRD-JOURNAL-D-12-00123.1>
- Yager K, Prieto M, Meneses RI (2021) Reframing pastoral practices of bofedal management to increase the resilience of Andean water towers. *Mountain Research and Development* **41**, A1-A9.
- Young KR, Alata E, Chimner RA, Boone RB, Bowser G, et al. (2023) Ecological change and livestock governance in a Peruvian National Park. *Land* **12**, 2051. <https://doi.org/10.3390/land12112051>

Case 15. Wetland conservation and restoration in the Canadian Prairie Pothole Region

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Site details

Item	Details	Remarks
Site name	Canadian Prairie Pothole Region (PPR)	Large complex of small wetlands within an intensive agricultural region covering 467,000 km ²
Contracting Party/Country	Canada	
GIS Coordinates	N/A	
Site ID	238, 239, 365, 366	<i>Wetland of International Importance in the Canadian PPR, but not representative of small wetlands in the region nor the focus of this case study</i>
RIS last updated	N/A	
RIS source	N/A	
Surface area of case site (ha)	467,000 km ²	
Wetland type	Marshes (on mineral soils)	
Agricultural system type	Rainfed intensive Livestock extensive	

Main key message

The Prairie Pothole Region, one of the world's largest wetland complexes, is embedded within Canada's largest, most productive agricultural region. The wetlands in this region are typically small mineral soil wetlands, known as prairie marshes or prairie potholes (less than 2 ha in size) ranging from ephemeral wetlands holding water for only a few weeks during the spring to permanent wetlands with water persisting continuously. These wetlands have historically faced significant loss and degradation from agricultural expansion. However, in recent decades, significant efforts to restore and protect these wetlands have focused on leveraging their value as agriculture and climate ecosystem-based solutions. Collaborations with industry and governments have resulted in programs which provide business-case solutions for wetland conservation.

The challenge presented by agricultural expansion and intensification in the Canadian Prairie Pothole Region

Agricultural expansion and intensification have resulted in significant wetland loss and degradation in the Canadian Prairie Pothole Region (PPR; Figure 1) over the last century. This region comprises over 50M hectares of farmland and accounts for more than 80% of Canada's agricultural landscape. The dominant crops produced are canola, wheat, and soy and this region is also the largest producer of beef cattle within Canada, as well as one of the main pork producing regions. Initially much of the wetland loss that occurred in this region was facilitated through government legislation that encouraged wetland drainage and expansion of agriculture to sustain the growing Canadian population in the late 1800s and early 1900s. Large-scale drainage projects drove the initial loss of wetlands, but additional wetland loss and degradation occurred throughout the Green Revolution because of greatly increased crop yields, which favoured further conversion of wetlands. This was accompanied by an exponential increase in the use of chemical fertilizers and pesticides after World War II, which further degraded the quality of the remaining wetlands through non-point source pollution. While wetland drainage in parts of the PPR has slowed over the last few decades, increases in equipment size and rising commodity prices continue to place pressure on the region's remaining wetlands.

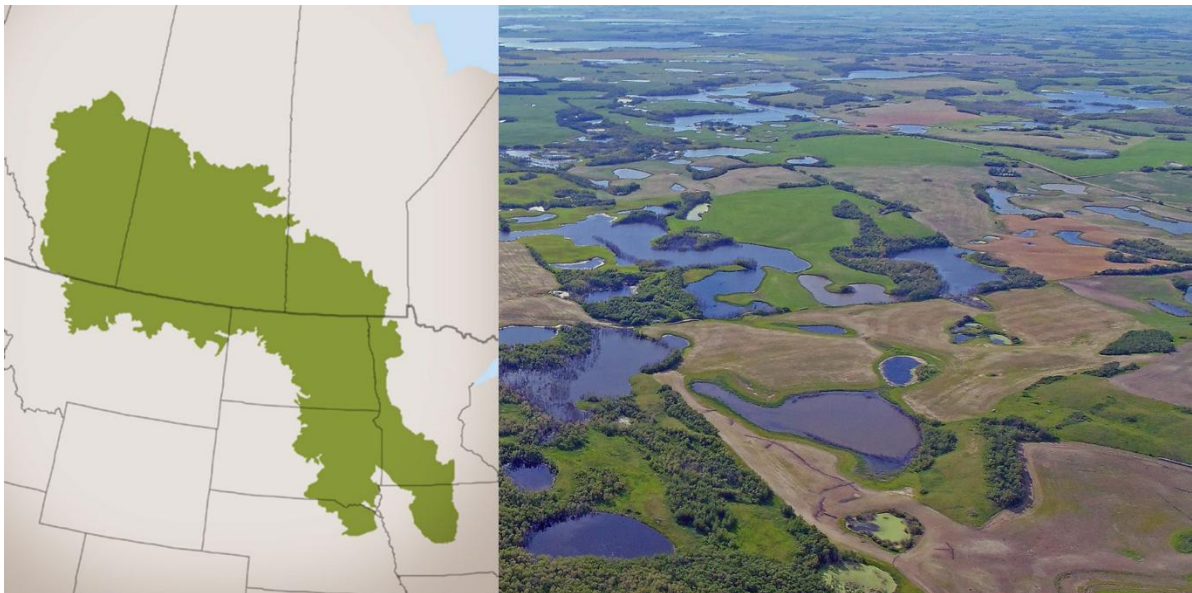


Figure 1. Map of the North American Prairie Pothole Region (left) and aerial photograph of a typical, wetland dense, agricultural landscape within the Canadian PPR (right). (© Ducks Unlimited Canada)

For more than 85 years, Ducks Unlimited Canada (DUC), a science-based registered charity, has been delivering wetland conservation and restoration programs across the Canadian landscape. While our programs initially focused on delivery of waterfowl habitat to sustain and maintain North America's waterfowl populations, we've long recognized that these habitats provide numerous other ecosystem services that are important to society. As a result, DUC has made significant investments in understanding and quantifying the full suite of wetland ecosystem services associated with our programs. Our work has resulted in significant wetland programming at both the provincial and federal levels, greatly increasing investments in wetland restoration in agricultural landscapes of Canada (Figure 2).

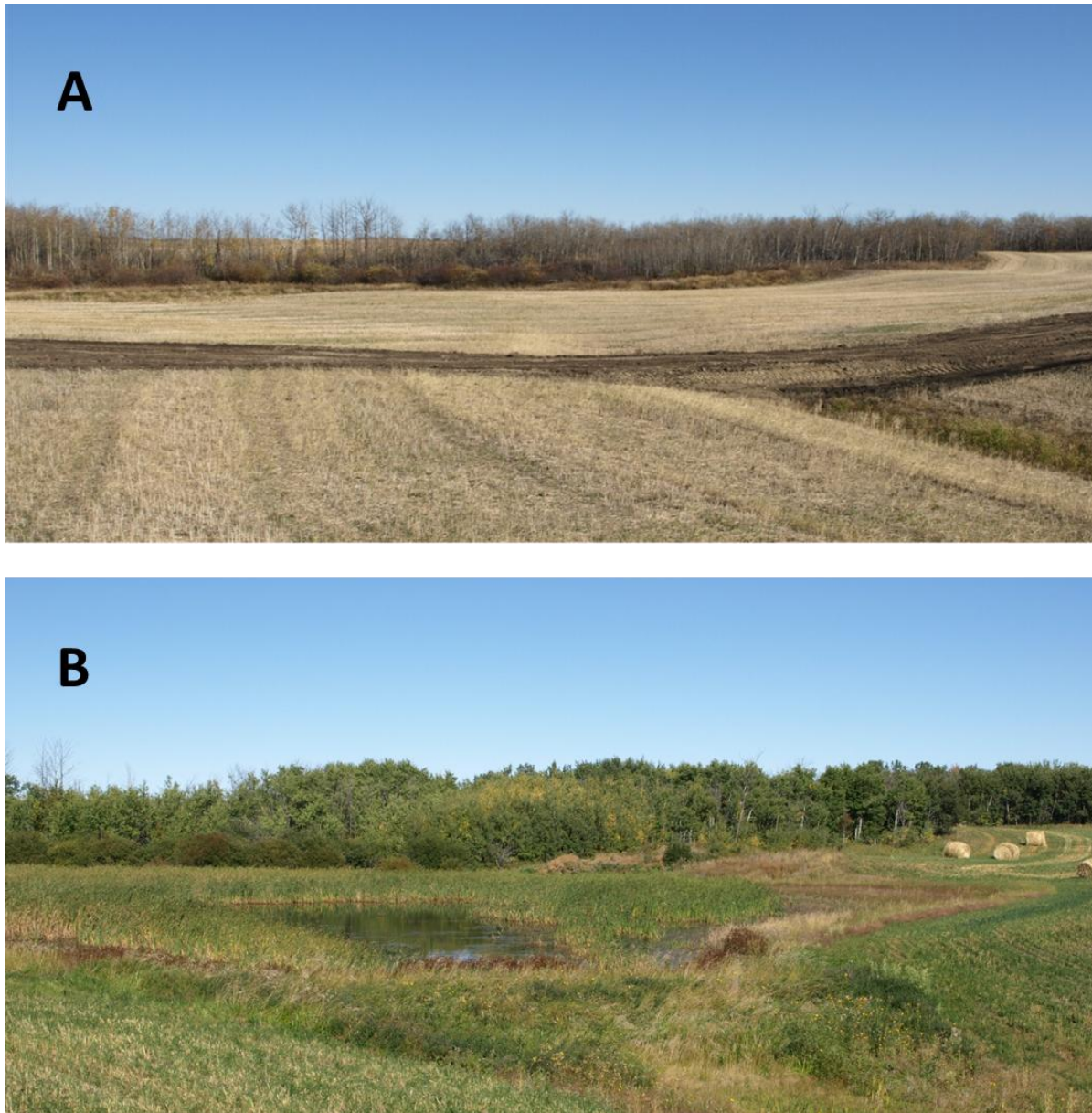


Figure 2. Photos of a prairie wetland A) pre (drained) and B) post restoration in the Canadian PPR.
(© Ducks Unlimited Canada)

Actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

Financial incentives are available to producers to assist with the cost of establishing forages. Whether the goal is to provide feed for livestock, add forage to cropping rotation, or restore trouble spots within annually cropped fields to forage, DUC's unique suite of forage programs can help to alleviate some of the financial burden associated with forage establishment. The Forage Program targets field scale plantings and has two term options available – 10 year (12 hectare minimum) or 15 year (30 hectare minimum). The Marginal Areas Program (MAP) targets areas within annually cropped fields where producers are seeing a negative return on investment due to poor yields due to poor soil conditions, periodic flooding, inaccessibility, and/or salinity.

b) Protecting wetlands and mitigating pressure/impact on wetlands

DUC undertakes habitat retention programs through direct acquisition of land, conservation easements and agreements with private landowners, and the implementation of best management practices (BMPs) to retain productive capacity of the landscape. Wetland Restoration programs involve the re-creation or enhancement of degraded or drained wetlands by returning hydrological or ecological function. We restore wetlands by simply plugging drainage ditches, or through more elaborate measures involving dykes, dams, and engineered water control structures.

Through our Revolving Land Conservation Program (RLCP), DUC purchases land, restores its wetlands and grasslands, and then makes it available to buyers with a conservation easement on the title. Proceeds from RLCP land sales go back into DUC programs to fund more conservation work. Between April 1, 2012 and March 31, 2023 DUC programs restored 44,634 ha of wetlands and conserved an additional 50,796 ha.

c) Supporting rural livelihoods, equity, and social well-being

DUC's agricultural programs help support rural economies and livelihoods by providing payments /incentives to help agricultural producers reduce costs associated with marginally productive landscapes.

d) Building resilience in people, communities, and ecosystems

DUC's agricultural programs help support resilient agricultural landscapes where nature-based solutions like wetlands help mitigate floods and droughts while also combatting climate change.

e) Responsible and effective governance and institutions

DUC has worked with all three provincial governments in the PPR to help inform wetland policy. Our work was directly involved in assisting the government of Manitoba in expanding and enhancing wetland regulations while also helping to inform wetland restoration/conservation incentives offered through the Manitoba Habitat Corporation. In the province of Alberta, our science was used to include wetland enhancement and restoration as part of the Watershed Resiliency and Restoration Program. At the federal level, DUC's research has helped shape investments in programs funding wetland restoration and conservation to enhance water quality in Canada's Great Lakes as well as investments in wetlands as nature-based climate solutions.

Conclusion

To achieve true sustainability, solutions to PPR wetland loss and degradation related to agricultural intensification must be delivered at scale across the region. This outcome can only be accomplished by collaborating with the agriculture industry. These working lands are owned and managed as businesses, hence decisions impacting wetlands are typically business-based, and the solutions must be as well.

Underpinned by DUC's research, we view our marginal areas, forage, and restoration programs as keys to a sustainable future because they directly help producers improve economic efficiencies while also resulting in demonstrable ecosystem and societal benefits. Meanwhile, our work with provincial and federal governments helps catalyse development of policies and programs that both guide industry and provide economic incentives for pursuing a sustainable path. Together, we believe these programs and collaborations with industry and governments can help reduce and reverse wetland loss and degradation in this economically and ecologically important region of Canada.

References

- Page B, Badiou P, Steele O (2023) Nutrient retention of newly restored wetlands receiving agricultural runoff in a temperate region of North America. *Ecological Engineering* **195**, 107060.
- Drever CR, Cook-Patton SC, Akhter F, Badiou PH, Chmura GL, et al. (2021) Natural climate solutions for Canada. *Science Advances* **7**, p.eabd6034.
- Pattison-Williams JK, Pomeroy JW, Badiou P, Gabor S (2018) Wetlands, flood control and ecosystem services in the Smith Creek Drainage Basin: A case study in Saskatchewan, Canada. *Ecological Economics* **147**, 36-47.
- Badiou P, McDougal R, Pennock D, Clark B (2011) Greenhouse gas emissions and carbon sequestration potential in restored wetlands of the Canadian prairie pothole region. *Wetlands Ecology and Management* **19**, 237-256.
- Yang W, Wang X, Liu Y, Gabor S, Boychuk L, Badiou P (2010) Simulated environmental effects of wetland restoration scenarios in a typical Canadian prairie watershed. *Wetlands Ecology and Management* **18**, 269-279.

Case 16. Managing the wetland ecosystem services of drainage ditches in agricultural landscapes in Ontario, Canada

Compiler(s) details

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Site details

Item	Details
Site name	Experimental Watersheds, Environmental Change OneHealth Observatory (ECO2): South Nation River
Contracting Party/Country	Canada
GIS Coordinates	Near Fairfield East, Leeds and Grenville County - 44°40'30"N 75°42'00"W 2 km east of Wendover, Prescott and Russell County - 45°34'23"N 75°06'00"W
Site ID	N/A
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	Roughly 3,500 linear km within South Nation River basin (~4,000km ²) for an estimated surface area of 3150 hectares; Ubiquitous throughout the region where intensive agriculture
Wetland type	Agricultural wetlands (drainage ditches)
Agricultural system type	Rainfed intensive; Livestock extensive

Main key message

Agricultural drainage ditches can be seasonally intermittent water conduits allowing the drawdown of excess water from adjacent fields. These ditches, depending on how they are managed, can act as flow-through type wetlands providing ecosystem services and functions within otherwise depauperate agricultural “field-scapes”.

The challenge presented by large-scale food production in relation to wetlands

Agriculture is spreading at the expense of natural capital. However, to support field cropping activities in many humid temperate regions of the world, field drainage is required to optimize crop productivity. Field drainage is usually in the form of artificial subsurface drainage and surface runoff.

Agricultural drainage ditches are built and designed to receive these forms of field drainage. These ditches are ubiquitous and necessary for agriculture in many regions of the world, and can become naturalized with wetland vegetation, accrue organic matter, and support wetland fauna and spawning habitat for fish.

An example are the agricultural drainage ditches in eastern Ontario, Canada (Figure 1) where they can be the only (semi) naturalized features in otherwise depauperate field landscapes, making them critical wildlife refugia for beneficial insects such as pollinators, biocontrol agents, and crop wild relatives, as well (Figure 2). Water quantity and quality required to sustain wildlife in these aquatic ditch systems support regenerative ecosystem functions – yet all ecological goods and services provided by the ditches, including carbon sequestration and regulating pollution by agro-chemicals, are directly controlled by how they are managed. In some cases, ditches can be excessively managed (channel dredging, bank clearing of all woody vegetation) to ensure flow efficiency. Less intensive management can foster naturalization into a kind of flow-through wetland supporting wetland functionalities and habitat. Management of these ditches is sanctioned by the producers that directly use the ditches for drainage; therefore, educating them on the ecosystem services they provide will help them optimize how they are managed to secure a win-win for the producers and environment.

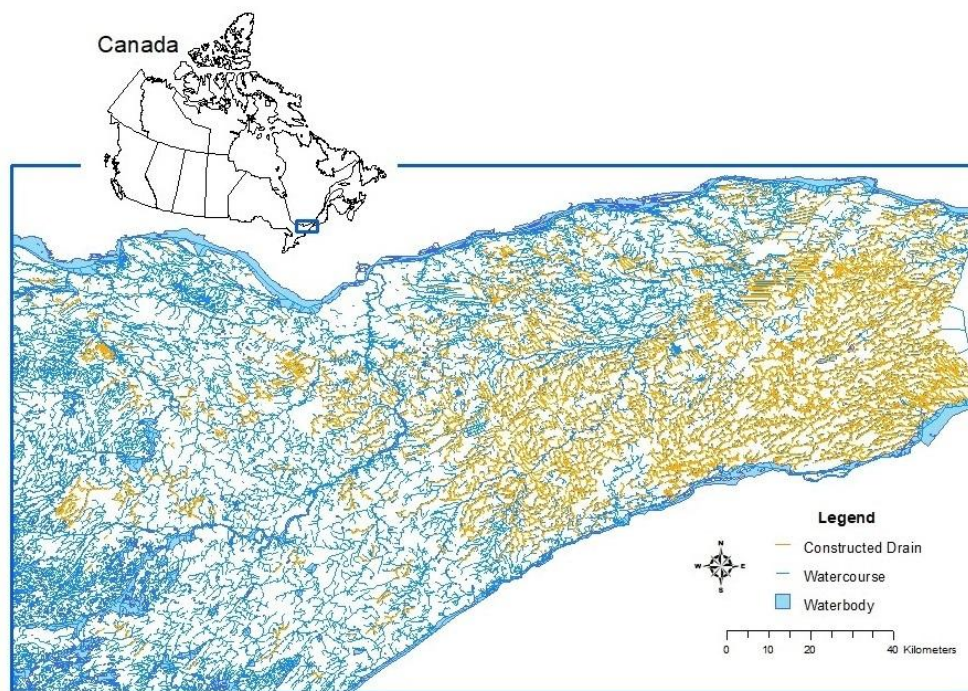


Figure 1. Agricultural drainage ditches (constructed drains) in eastern Ontario, Canada in case study area. Note that the width of many of these drainage ditches, shoulder-slope to adjacent shoulder-slope, can be ~10m - offering aquatic ecosystem habitat and marginal riparian and terrestrial bank habitat for wildlife. (© Agriculture and Agri-Food Canada)

The ditches require maintenance to function efficiently. Maintenance frequency can vary depending on the desire and monetary capacity of producers impacted. Maintenance would include channel dredging and woody vegetation clearing along banks to facilitate operation of heavy dredging equipment. How this is done in an ecologically-environmentally friendly manner is still not fully understood. Further, these ditch systems may be the only (semi)aquatic systems in these kinds of landscapes. Making them key refugia for wildlife; many of which are useful for pest control of public health and agricultural relevance. Generally, however, little if any resources are required by producers on a routine basis to tend to ditch function. In other words, these ditches just ‘do their thing’ with

little management by producers on a day-to-day basis. Some periodic activity by producers may be required to reduce log jams, beaver dams etc. that block stream flow, however. But outside of dredging/clearing interventions, these systems can be left alone to function.



Figure 2: Agricultural drainage ditches, displaying wetland-type features. Clockwise from top left: ditch prior to dredging; ditch after brushing of woody vegetation and dredging; ditch regeneration post-brushing. (© Agriculture and Agri-Food Canada)

Actions or opportunities for actions to make the system more sustainable

a) Options for increasing resource use efficiency

- Reducing dredging intensity/frequency: Given that producers/landowners pay for ditch maintenance, reducing interventions would save them money. Dredging can cost individual producers/landowners tens of thousands of dollars depending on the nature of the drainage course and property frontage with the ditch system. Reducing drainage ditch management to the ditches and times such management is absolutely necessary, will ultimately help reduce loss of wetland functionality of these systems in the region of interest.
- Reducing intensity/frequency of woody vegetation removal along agricultural ditch banks: As clearing/brushing equipment and associated operators would be needed for such activities and paid for by producers/landowners, cost savings in the context of vegetation removal reductions could otherwise be used to help support other farming activities.
- Harvesting ditch margins: While there are options for producers to utilize this area as an agricultural resource (harvesting of riparian vegetation for forage which is done in the region), they are unlikely to pursue these options due to preference to their primary agricultural activities.

b) Protecting wetlands and mitigating pressure/impact on wetlands

- Channel/bank biodiversity: Limiting ditch management interventions as per section a), will provide refugia for biocontrol/pollinators which can directly support agriculture, support critical terrestrial/aquatic wildlife habitat including species of concern/risk, provide in-situ conservation of crop wild relatives and plants of Indigenous relevance.

- **Additional co-benefits of Minimal Ditch Management:** Carbon sequestration can increase through increased woody vegetation growth. Lower soil organic carbon decomposition rates can also occur in and along the ditches where soil water contents are generally higher. The vegetation, such as macrophytes, in the channel can help biofilter agro-chemicals derived from adjacent field crops. Vegetation along and in the channel can provide habitat for bats and birds that prey upon pests that have agronomic and public health relevance. Woody vegetation along ditch banks can perform as windbreaks to reduce crop loss to wind and increase shade supporting cooler water aquatic species. Reducing land clearing activities can reduce invasive/weedy plant species.

c) Supporting rural livelihoods, equity, and social well-being

Many agricultural ditches are located on privately owned land, yet maintained by municipalities which are constructed under Ontario's Drainage Act and have legal status. Landowners are required to communally pay for drain maintenance based on the contributing surface areas of their properties to the drain. Table 1 provides a governance/decision making model for these drainage systems. Often maintenance is conducted for a perceived benefit on drainage efficiency (at great cost), but in many cases maintenance does not improve flow efficiency, and the naturalized wetland functionalities of non-managed ditches can be retained. In this case, producers and municipalities can save money by leaving the systems un-managed.

Cost-sharing through provincial grants often offsets a portion of maintenance costs, reducing the burden on producers and Province. Ontario conservation authorities such as South Nation Conservation provide clean water cost sharing programs and nutrient trading programs for projects that improve water quality. On a case-by-case basis, enhancement and protection of riparian zones is a key type of project (<https://www.nation.on.ca/water/grant-programs/clean-water-program>).

Key environmental NGOs, municipal, provincial, and federal partners are included in providing outreach and education to local landowners on the ecosystem goods and services provided by ditches.

d) Building resilience in people, communities, and ecosystems

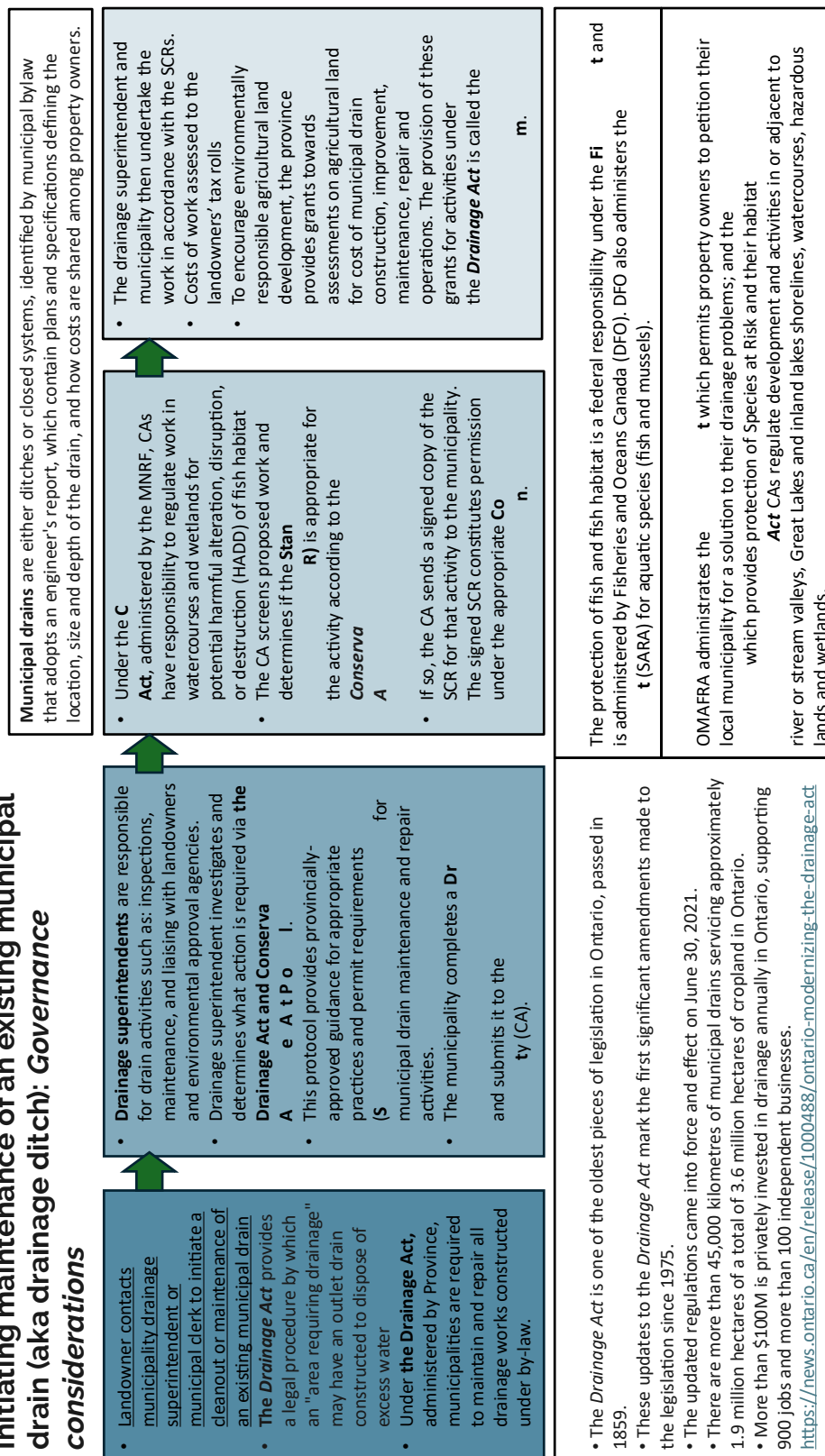
Ecosystem goods and services provided by the wetland disposition of agricultural drainage ditches (as noted above) helps increase the resilience of the regional agro-ecosystem by supporting concurrently agricultural production, and environmental and public health endpoints. These are true One Health attributes. The ditches are also critical in the local-regional agricultural value chain by: (1) Providing drainage necessary to augment yields for producers (increasing economic returns); and (2) Improving soil quality by increasing field drainage (i.e., reduce soil compaction) – which has long lasting positive impacts on crop production (and economic returns). Ditch functioning is necessary in these humid-temperate regions to facilitate a healthy agricultural economy.

Trade-offs between wetland ecosystem services and food production are considered. The ditches are human made and necessities for field drainage. Co-benefits are the wetland ecosystem goods and services associated with ditch systems and bank vegetation management. Thus, they do not represent a loss of productive land per se. Ditch edge vegetation can be managed to address shading impacts on field crops without minimizing bank ecosystem services which are considerable in their own right.

Table 1. Ditch management decision and governance flow chart documenting the stages for approval and some of the Acts and regulations such management must abide by.

Unclassified / Non classifié

Initiating maintenance of an existing municipal drain (aka drainage ditch): Governance considerations



e) Responsible and effective governance and institutions

Many levels of governance are involved if an agricultural drainage ditch is classified as a municipal drain, including but not limited to: Federal departments of Fisheries and Oceans; Municipalities and Conservation Authorities; provincial Ministries of the Environment and Climate Change and Agriculture, Food and Rural Affairs. Drainage ditches constructed under Ontario's Drainage Act have legal status and the municipality is responsible for ensuring that necessary maintenance and repairs to drains are done by the municipality. Municipal drains are also considered fish habitat, subject to the Fisheries Act and fish habitat protection. Provisions and maintenance on certain drains therefore requires authorization from the Department of Fisheries and Oceans. The Conservation Authorities Act gives Conservation Authorities regulatory powers over activities adjacent to watercourses (including drains) and to require permits for these works.

Drainage superintendents of Ontario (<https://dsao.net/>) on behalf of municipalities, are responsible for the management of municipal drains (agricultural drainage ditches) already, and try to reduce the amount of tree and substrate removal to reduce costs incurred by landowners and minimize impacts on associated aquatic and terrestrial ecosystems (i.e., removing just enough material required to maintain original ditch hydrologic functions). Ontario conservation authorities provide rural clean water programs and nutrient and ecosystem services trading programs for projects that improve water quality. On a case-by-case basis, enhancement and protection of riparian zones is a key type of project (e.g., <https://www.nation.on.ca/water/grant-programs/ottawa-rural-clean-water-program>; or the wetland drain restoration project developed by the Ontario Ministry of Natural Resources and forests: https://www.abca.ca/downloads/MNR_Wetland_Restoration_-_final_26Feb07b.pdf).

Key environmental NGOs, municipal, provincial, and federal partners, and local landowners have been included in local research on impacts of ditch dredging and tree clearing on the ecosystem services provided by biodiversity. Environmental NGOs providing support for ecosystem services improvements include Ducks Unlimited Canada (<https://www.ducks.ca/places/ontario/wetlands-at-work/>); Alternative Land Use Services (ALUS; <https://alus.ca/what-we-do/>); and Ontario Soil and Crop Improvement Association (<https://www.ontariosoilcrop.org/cost-share-programs/>).

Conclusion

In the experience of the compilers, agricultural drainage ditches may represent the most salient 'wetland'-type systems in humid temperate regions of the world where field drainage is required to optimize crop productivity. They can represent thousands of linear km in watersheds (representing a substantial surface area) providing the only (semi)aquatic ecosystems available for wetland-type flora and fauna. The ecosystem services provided by these human-made systems are numerous: including refugia for wildlife, carbon sequestration, water filtering of agro-chemicals, and provision of drainage required to optimize crop productivity. Management of these ditches can be conducted in a manner that provides a win-win for the environment and agriculture. They are not features that take land out of production and are considered part of the constructive agro-ecosystem by producers and watershed stewards alike. Based on producer testimonials regarding incentives/disincentives with respect to adoption of other drainage management practices in these landscapes, it is felt that the main arena for incentivising minimal management of drainage ditches to support their wetland functionalities, is having municipalities and drainage superintendents communicating to producers the degree of monetary savings brought about dredging/clearing only when absolutely necessary to maintain flow efficiency. This, we feel, would be a mode of soft governance provisioned by regulatory bodies; with the most salient mode for change falling under category 'e' [Responsible and Effective Governance and Institutions], and category 'c' [Supporting rural livelihoods, Equity, and Social Well Being] via capacity for limited management to indirectly keep tens of thousands of dollars in the

pocket of landowners and not ‘down the drain’, so to speak, for actions that would have limited effect on nominal field operations.

References

- Damphousse L, van Goethem K, Carroll E, Stammer K, Febria C (2023) Ecological impacts of management practices in agricultural drain networks: a literature synthesis. *Canadian Water Resources Journal/Revue Canadienne des Ressources Hydriques* **49**, 329-354.
- Herzon I, Helenius J (2008) Agricultural drainage ditches, their biological importance and functioning. *Biological Conservation* **141**, 1171-1183.
- Rideout NK, Lapen DR, Peters DL, Baird DJ (2022) Ditch the low flow: Agricultural impacts on flow regimes and consequences for aquatic ecosystem functions. *Ecohydrology* **15**, p.e2364.
- Needelman BA, Kleinman PJ, Strock JS, Allen AL (2007) Drainage Ditches: Improved management of agricultural drainage ditches for water quality protection: an overview. *Journal of Soil and Water Conservation* **62**, 171-178.
- Blann KL, Anderson JL, Sands GR, Vondracek B (2009) Effects of agricultural drainage on aquatic ecosystems: a review. *Critical Reviews in Environmental Science and Technology* **39**, 909-1001.
- Dollinger J, Dagès C, Bailly JS, Lagacherie P, Voltz M (2015) Managing ditches for agroecological engineering of landscape. A review. *Agronomy for Sustainable Development* **35**, 999-1020.
- Kavanagh RJ, Wren L, Hoggarth CT, Burlington O (2017) Guidance for maintaining and repairing municipal drains in Ontario. *Fisheries and Oceans Canada, Burlington, ON*.

Case 17. The US Department of Agriculture wetland conservation and restoration program: quantifying ecosystem services from wetland restoration to benefit water quality and climate

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Site details

Item	Details
Site name	Agricultural areas throughout the US
Contracting Party/Country	USA
GIS Coordinates	N/A
Site ID	N/A
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	N/A
Wetland type	Marshes and riparian zones (on mineral soils)
Agricultural system type	Rainfed intensive

Main key message

Wetlands that are integrated into agricultural landscapes provide a range of social and ecological benefits, including water quality improvement (through nutrient retention and removal, carbon sequestration, biodiversity support, and water retention and storage). In response to environmental degradation and high rates of wetland loss, the US Department of Agriculture (USDA) established the Conservation Reserve Program (CRP), initially to reduce soil erosion and later, along with the Wetland Reserve Program (WRP), to promote a suite of conservation practices including wetland and riparian zone restoration on private farmland across the U.S. To date, over 1.2 million hectares of wetlands have been restored. Under this program, landowners receive financial and technical assistance from the USDA to take cropland out of production and restore and enhance wetlands lost or degraded by agricultural land use. Assessments of the impact of conservation programs over large, intensively farmed regions, shows a significant increase in the benefits wetland provide, including for water quality and climate mitigation. Biodiversity and habitat benefits are also evident. These conservation programs provide important long-term benefits; however, these can be limited because of program administration, which limits contracts with landowners to 10-15 years. At that time contracts expire and the land may be converted back to crop production. This case study focuses on the benefits that can be realized through a government sponsored policy to reintegrate wetlands across large areas of farmland.

The challenge presented by the loss of wetlands in the Midwestern agricultural region of the US

Over the past 200 years, 40-90% of the historic wetland area have been drained in the agricultural regions of the U.S. (including the Midwest, Great Plains, and central valley of California; Dahl 1990, 2014). Wetland losses are greatest in the Midwestern region of the U.S., also known as the Corn Belt, where states have experienced wetland losses of up to 90% as a result of conversion to row-crop agriculture (Dahl 1990). The historical loss of wetlands resulted in the expansion of highly productive agricultural land, but a loss in the delivery of ecosystem services (Zedler 2003; Fennessy and Craft 2011).



Figure 1. Prairie pothole CRP wetland. (© Siobhan Fennessy)

Farmers in the U.S. Midwestern states manage over 51 million hectares of land, so national programs that support wetland restoration can diversify agricultural landscapes and contribute to the reestablishment of beneficial ecosystem services. The loss of wetland benefits is apparent, for example in the widespread, chronic water quality problems, increased flooding, and a loss of biological diversity in the region. For example, runoff from agricultural fields is a major driver for the Gulf of Mexico dead zone, a vast area of oxygen-depleted water caused by nitrogen and phosphorus inputs from the Mississippi River Basin. Low oxygen levels in the dead zone lead to fish and shellfish kills, and economic impacts are estimated to be about \$82 million USD annually (www.NOAA.gov).

Water quality degradation resulting from wetland losses also affects the Great Lakes. This has caused large scale eutrophication and chronic algal blooms, including harmful algal blooms (HABs), particularly in Lake Erie. HABs result from the explosive growth of the cyanobacteria (blue-green algae) that produce liver and neurological toxins and can lead to illness and or death in humans and animals (both (e.g., fish, dogs). In addition, the accumulation of HAB toxins recently caused a three-day ban on drinking water for approximately half a million people in northwestern Ohio. The land area that feeds this part of Lake Erie was once a 400,000 ha freshwater swamp (the Great Black Swamp), which was completely drained for agriculture. While this area is vital for food production, estimates are that wetland restoration of between 1% – 10% of this area could lead to significant improvements in water quality and biological diversity (Mitsch 2017).



Figure 2. Ohio farmland with former wetland area. (© Siobhan Fennessy)

Actions or opportunities to make the system more sustainable

a) Options for increasing resource use efficiency

An overarching goal of the CRP is to optimize the use of natural and agricultural resources (soil, water, nutrients, energy, and biodiversity) to provide environmental benefits. The CRP aims to increase resource use efficiency by reducing soil and water runoff, enhancing ecosystem services, and improving agricultural productivity over the long term. Some key practices include (The Nature Conservancy; www.nature.org):

- Cover Crops – Planting cover crops like rye, clover, and tillage radish during the off-season to reduce soil erosion, improve water retention, break up compacted soil, and increase soil organic matter and nitrogen content
- No-Till and Reduced-Till Farming – It is estimated that nearly 75% of farmland in the Midwest is now under no-till or reduced till. By minimizing soil disturbance, these practices help reduce erosion, improve soil quality, and lower carbon emissions from soil and farming equipment (<https://www.no-tillfarmer.com>).
- Precision Agriculture – The use of technologies such as GPS-guided tractors, monitoring with drones, and soil sensors help farmers gather information to apply fertilizers, pesticides, and water more efficiently, reducing waste and runoff. This uses resources more efficiently, and can increase yields, reduce costs, and reduce the flux of agricultural chemicals downstream.
- Edge-of-Field Conservation Practices – This includes restoration of riparian buffer strips, wetlands, and prairie strips to protect soil and water quality, while providing habitat for wildlife. Prairie strips (including wet prairies) are in-field contour buffer strips planted with a diversity of native plants. It's been shown that converting as little as 10% of a field can reduce soil erosion by 95% (Schulte et al. 2017).

b) Protecting wetlands and mitigating pressure/impact on wetlands

The Conservation Reserve Program was established in 1985, and as of 2020 had restored over 1.2 million hectares of wetland and 175,000 stream miles (<https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/crp-2020>). Working with the USDA and county level extension offices, landowners can retire environmentally sensitive land from agricultural production. In exchange for yearly rental payments, wetlands are restored with CRP

contracts typically lasting 10-15 years. Overall, the program offers support for over 30 different conservation practices, not all of which are related to wetlands, including grassland and forest restoration (Farm Service Agency 2023). To qualify, land must have been planted with an agricultural commodity for a minimum of four of the past six crop years. The Farm Service Agency (FSA) uses the Environmental Benefits Index (EBI) to assess and rank the potential environmental benefits of the proposed project. A minimum EBI is set by the Secretary of Agriculture on a yearly basis, making eligibility criteria dynamic.

Over the first 20 years of the program (1985 - 2005, little work was done to measure the effectiveness of these conservation measures. To address this knowledge gap, the USDA developed the Conservation Effects Assessment Project-Wetlands (CEAP; <https://www.nrcs.usda.gov/ceap>) to show the benefits provided by restored wetlands, and to improve wetland conservation efforts going forward. As a result, under CEAP the ability of wetlands to improve water quality has been investigated in agricultural regions across the US (Brinson and Eckles 2011). In one study, three types of wetlands were evaluated: restored depressional wetlands, restored riparian wetlands (sometimes called riparian buffer zones) and natural riparian wetlands (as a control). Agricultural fields adjacent to the restored sites were also studied to serve as a baseline and assess the gain in ecosystem services following restoration (Fennessy and Craft 2011).

Results show that the lost water quality benefits were regained over time, however, the delivery of this ecosystem service differs by wetland type. For instance, nitrogen uptake by wetlands was greatest in riparian wetland buffers, while phosphorus removal was greatest in depressional sites. The average ($\pm$ standard error) phosphorus retention in depressional wetlands (40.3 ± 3.1 mg P/100 g soil) was greater than in natural riparian (18.7 ± 1.2 mg P/100 g soil) and restored riparian (18.9 ± 1.1 mg P/100 g soil) zones. All wetland types removed more nitrogen and stored more carbon than the surrounding agricultural soils, and the data show that as the amount of soil carbon increased, nitrogen removal, measured as denitrification rates, also increased. Nitrogen uptake was greater in the natural (265 ng N₂O/g soil/hr) and restored (190 ng N₂O/g soil/hr) riparian buffers, with lower rates in the depressional wetlands (38 ng N₂O/g soil/hr; Marton et al. 2013). In another study, restoration of 6% of a crop field reduced water runoff by 8%, and dissolved nitrogen and phosphorus by 29% and 28%, respectively (McKenna et al. 2020). The return on investment in the CPR programs can be high.

Carbon sequestration in agricultural soils and restored wetlands is also being promoted to mitigate GHG emissions. Despite the understanding that wetlands can sequester soil organic carbon (SOC) approximately 5 times faster than restored grasslands (Euliss et al. 2006), there has been relatively little focus on the climate benefits of restoration of the millions of drained wetlands embedded in the agricultural landscapes of the U.S. Several projects are on-going to document these benefits.

c) Supporting rural livelihoods, equity, and social well-being

In the CRP, wetland protection, conservation, and restoration are implemented through voluntary, incentive-based programs. Participating farms are supported with annual rental payments, which vary based on factors such as soil productivity, local rental rates, and specific conservation practices. For wetland restoration practices, these payments typically range between USD \$210 to \$310 per hectare. (<https://www.fsa.usda.gov/programs-and-services/conservation-programs-old>). There is also cost share assistance that can cover up to 50% of the participant's costs for restoration.

The WRP operates through the government purchase of conservation easements. Here the farmer retains ownership of the land, but activities on that land are limited to wetland restoration. Under WRP, there is a cap on the land area that can be purchased for easements. Applications are evaluated based on estimates of the project's environmental benefits, cost-effectiveness, productivity of the

land, environmental threats if the land stays in crop production, and whether the landowner can contribute to the cost of the easement.



Figure 3. Researchers taking samples in Wetland Reserve Program wetland. (© Siobhan Fennessy)

Farmers enroll in CRP and WRP for reasons other than financial incentives, including environmental benefits. Many participants say they are motivated to participate by the environmental benefits that CRP practices provide, particularly when they understand the links between wetland conservation and improvements in water quality and quantity. This motivation is essential to support a voluntary system (Blauser 2011, Reimer and Prokopy 2014). In contrast, an economic challenge comes from the fact that payments are often lower compared to revenues from crops. Many farmers already face financial struggles, with 42% classified as low-income households. This too, can limit participation (King et al. 2021).

There is also concern over the long-term contract commitments (10-15 years), and complex application processes. In some regions, scepticism toward government programs can also deter participation. If higher payments and streamlined application procedures were made available, enrolment could increase. However, in many years, the number of applications exceeds the acreage caps set on the program so not all applications are funded; this makes the selection process competitive. There are also broader unintended consequences to consider, including that some farm subsidies assist with water infrastructure programs, which can contribute to over-irrigation by incentivizing excessive water use. Ultimately this leads to unsustainable water use patterns. The CRP is thought to help address this by removing some marginal lands from participation, although participation in CRP by large, profitable farms that make extensive use of irrigation is limited (King et al. 2021).

d) Building resilience in people, communities, and ecosystems

The CRP and WRP can contribute to rural community resilience by enhancing soil quality, water security, stabilizing farm incomes, all of which strengthen local economies.

- By improving water quality and water retention, it protects critical water resources for farms, local rural communities, and downstream areas. For example, work in the

Chesapeake Bay drainage basin targets wetland and riparian zone restoration as a means to improve ecological conditions and fisheries in the Bay.

- Wetlands take up and store carbon, providing a means to mitigate greenhouse gas emissions and climate change impacts.
- CRP wetlands and grasslands support pollinator species, making agricultural ecosystems more diverse and resilient.
- The CRP program support rural economies by providing rental payments and cost-share assistance to farmers. It can also lead to job creation in associated fields, for example supporting conservation consultants, land managers, and extension agents who work with farmers to apply for and implement conservation projects.

e) Responsible and effective governance and institutions

The first Farm Bill was passed in 1933 in response to the Great Depression and the Dust Bowl, which struck the Great Plains region of the US between 1930-1940. The Dust Bowl, caused by an extended drought and unsustainable farming practices (removing native prairie grasses that hold soil in place and over-plowing), led to catastrophic losses of top soil in wind storms. Approximately 1.2 billion tons of soil were lost, and in the worst storm in 1935, in one day the wind blew away twice as much total soil as was excavated to create the Panama Canal (<https://www.britannica.com/place/Dust-Bowl>). This caused a state of emergency to be declared by the US congress, who passed the first Farm Bill containing price supports to stabilize crop markets and conservation programs to better manage farm soils (Blauser 2011).

In the years since, the conservation programs have developed, as has the bureaucracy that supports them. For instance, each of the approximately 30 conservation programs under the Farm Bill have different enrolment processes. It is common for farmers to 'bundle' conservation practices, so the need to fill out different forms for each is a barrier to entry. Streamlining the process would benefit farmers and the USDA employees who work with them. There is also concern that monitoring and enforcement of the program is too invasive. Agents can stop by without warning to inspect a farm, and while compliance is high, farmers may resent the intrusion, preferring to have a say about when site inspections are scheduled. Finally, the CPR and WRP programs are underfunded, limiting the benefits they can provide (Blauser 2011).

Conclusion

The CRP programs that promote wetland restoration have resulted in the reestablishment of over 1.2 million hectares of wetland across the agricultural regions of the US. While it was always assumed that these wetlands were providing benefits, the CEAP program to quantify those benefits began in the early 2000s, and is on-going. This work shows that wetland restoration can provide substantial benefits to water quality, and water and soil carbon storage. Other important services related to biodiversity and habitat enhancement are also re-established. All of these contribute to more sustainable and diverse agricultural landscapes. However, the effectiveness of the conservation programs to provide long-term benefits is compromised because CRP contracts with landowner's expire after 10-15 years, at which time the land maybe converted back to crop production. The chronic underfunding of both the CPR and WRP programs also limits the benefits they can provide.

References

- Blauser MB (2011) The 2008 farm bill: friend or foe to conservationists and what improvements are needed. *Vermont Journal of Environmental Law* **12**, 547-570.
- Brinson M, Eckles D (2011) U.S. Department of Agriculture conservation program and practice effects on wetland ecosystem services: a synthesis. *Ecological Applications* **21**, S116-S127
- Dahl TE (1990) Wetland losses in the United States: 1780's to 1980's. U.S. Fish and Wildlife Service, Washington, D.C., USA.
- Dahl TE (2014) Status and trends of prairie wetlands in the United States 1997 to 2009 (p. 67). Washington, DC: US Fish and Wildlife Service.
- Euliss Jr, NH, Gleason RA, Olness A, McDougal RL, Murkin HR, et al. (2006) North American prairie wetlands are important nonforested land-based carbon storage sites. *Science of the Total Environment* **361**, 179-188. <https://doi.org/10.1016/j.scitotenv.2005.06.007>.
- Fennessy MS, Craft CB (2011) Agricultural conservation practices increase wetland ecosystem services in the Glaciated Interior Plains. *Ecological Applications* **21(3 Supplement)**, S49-S64.
- King SL, Laubhan MK, Tashjian P, Vradenburg J, Fredrickson L (2021) Wetland Conservation: Challenges Related to Water Law and Farm Policy. *Wetlands* **41**, 54. <https://doi.org/10.1007/s13157-021-01449-y>
- McKenna OP, Mushet DM, Behrman KD, Osorio JM, Doro L (2020) Development of a novel framework for modeling field-scale conservation effects of depressional wetlands in agricultural landscapes. *Journal of Soil and Water Conservation* **75**, 695-703.
- Mitsch WJ (2017) Solving Lake Erie's harmful algal blooms by restoring the Great Black Swamp in Ohio. *Ecological Engineering* **108**, 406-413.
- Reimer AP, Prokopy LS (2014) Farmer Participation in U.S. Farm Bill Conservation Programs. *Environmental Management* **53**, 318-332. doi: 10.1007/s00267-013-0184-8
- Zedler JB (2003) Wetlands at your service: reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and the Environment* **1**, 65-72.

Some useful links:

- Brittanica.com: Dustbowl. <https://www.britannica.com/place/Dust-Bowl>
- The Nature Conservancy Great Lakes - Agriculture in the Midwest: "Growing clean water" while feeding the world. <https://www.nature.org/en-us/about-us/where-we-work/priority-landscapes/great-lakes/great-lakes-agriculture-/#:~:text=The%20Midwest%20is%20known%20for,of%20the%20country's%20dairy%20products>
- US Department of Agriculture, Natural Resources Conservation Service: Conservation Reserve Program. <https://www.nrcs.usda.gov/programs-initiatives/crp-conservation-reserve-program>
- US Department of Agriculture, Natural Resources Conservation Service: Wetland assessments. [https://www.fsa.usda.gov/Internet/FSA_File/crp_wetland_pamphlet.pdfhttps://www.nrcs.usda.gov/ceap/wetlands#:~:text=Conservation%20Effects%20Assessment%20Project%20\(CEAP,both%20regional%20and%20national%20scales](https://www.fsa.usda.gov/Internet/FSA_File/crp_wetland_pamphlet.pdfhttps://www.nrcs.usda.gov/ceap/wetlands#:~:text=Conservation%20Effects%20Assessment%20Project%20(CEAP,both%20regional%20and%20national%20scales)

Case 18. Environmental water allocations to maintain the ecological character of wetlands in the Murray-Darling Basin, Australia

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Site details

Item	Details
Site name	Murray-Darling Basin
Contracting Party/Country	Australia
GIS Coordinates	N/A
Site ID	Basin contains 16 individual Wetlands of International Importance.
RIS last updated	N/A
RIS source	N/A
Surface area of case site (ha)	106,150,000 ha
Wetland type	Rivers, streams, floodplains; Lakes
Agricultural system type	Irrigated; Rainfed extensive, intensive; Livestock extensive, intensive; Horticulture

Main key message

The Murray-Darling Basin in south-eastern Australia is a large-scale effort to reverse the degradation of rivers and wetlands due to the expansion of irrigated agriculture. Water has been reallocated for environmental purposes through a federal water plan; implementation is complex and contentious due to the social and economic implications.

The challenge presented by environmental water allocations to conserve wetlands in the Murray Darling basin

The Murray-Darling Basin in south-eastern Australia, covers about 1 million km² of land and contains Australia's longest rivers, the Murray (2375 km), the Murrumbidgee (1,485 km) and the Darling (1,472 km) with around 20 other major rivers, most of which flow into the Murray or Darling rivers before the Murray eventually reaches the Southern Ocean. The estimated area of wetlands in the Basin is 5.7 million hectares, with 16 listed as Wetlands of International Importance. As rainfall across the Basin is temporally and spatially variable (Chiew et al. 2008), many of the rivers are ephemeral, averaging 457 mm annually, with more in the south-east (>1500 mm) and east, and less in the west (<300 mm). In the north, most rainfall occurs in summer, whereas in the south most occurs in winter. Evaporation is four times higher than rainfall with only 6% runoff to the streams and to recharge the groundwater (Chiew et al. 2008).

Agricultural development has led to major changes in the landscape with large areas of native vegetation cleared for both rainfed and irrigated agriculture, and the river flows regulated through the construction of weirs and dams, and water extracted and allocated for irrigated agriculture (Figure 1). The rapid expansion of irrigated agriculture, in particular, led to concerns over the ecological condition of the rivers and wetlands, coming to a head in the early 2000s during an extensive drought, temporally and spatially (Kingsford et al. 2009; Pittock and Finlayson 2011). At that time, irrigated land covered approximately 2% of the land area of the Basin, while using 90% of diverted waters to produce 70% of Australia's irrigated agricultural output, valued at AUD 7 billion per year (ABS et al. 2009). Concern over the state of the rivers and wetlands amidst the economic downturn of the drought led to serious questions about the sustainability of irrigation, and to political responses to reverse the environmental decline and restore the rivers and wetlands (Connell 2007; Kingsford et al. 2009).



Figure 1. Irrigated agriculture in the Murray Darling basin, with nut plantations (left) and grapes for wine production (right). (© Max Finlayson)

In response, the Australian Federal Government and State Governments that cover parts of the Basin developed a plan to manage the water and restore the ecological condition of the rivers and wetlands through the allocation of 2750 GL of water specifically for environmental purposes (Neave et al. 2015). The Murray-Darling Basin Plan was signed into law in November 2012 and provided a framework to share water between all users and the environment in a sustainable manner (Hart 2015). The Plan sets limits on how much water can be taken for multiple uses, including for irrigation, urban and industrial uses, and other uses as agreed. The limits on water extractions came into effect in 2019, and are due for review in 2026. Here we describe experiences and progress with the implementation of the Murray-Darling Basin Plan; we do not provide a systematic review of all aspects of the implementation.

Actions or opportunities to make the system more sustainable

The analysis makes reference to the diversity in wetlands and farming systems outlined in van Dam et al. (2025) with a key message being that the complexity of managing water across a large basin that comprises distinct climate zones and social-economic settings requires both an over-arching context and multiple local actions that reflect the settings, which in themselves may change as a consequence of the implementation of the water planning as well as in response to independent drivers.

a) Options for increasing resource use efficiency

The efficient use and water allocations for irrigated agriculture across the sub-catchments in the Basin have been addressed through the determination of sustainable water diversions from the individual rivers, with a water market established to enable adjustments to water entitlements and allocations to individual farming enterprises, and supported by sub-basin water management plans. On the water market governmental environmental water holders are responsible for purchasing water specifically for environmental purposes (Connell and Grafton 2011). The water planning is managed by a Federal Government body – the Murray-Darling Basin Authority (MDBA) – in consultation with State Governments with specific agreements that reflect their mandated responsibilities for land and water management and for the wider social-economic settings, such as those for agriculture and food processing.

For some time measures have been taken to improve water use efficiencies on farms across the Basin through improved water distribution for cropping across large areas, including techniques such as laser-levelling of fields to enable even water distribution, and the drip irrigation to individual plants in perennial crops. Previously unlined delivery canals are being lined with impervious materials to reduce water leakage, and advanced meters have been installed to measure water usage of specific users. Such measures are ongoing with investment from both individuals and governments (Holland et al. 2015; Mallawaarachchi et al. 2020).

Farming enterprises, including family properties and corporate entities, are able to make their own decisions around farming activities within general land and water management policies enacted through state governments, and the opportunities and constraints provided by market mechanisms and their individual business models. The size of farming properties varies in relation to their location across the basin and the particular agricultural practices. As it is a large basin with a range of climates the range of products produced is also large, and subject to change. Irrigated agriculture includes broad-area cropping of rice and cotton, as well as wheat, corn and soybeans, grazing for meat and dairy products, and horticulture including for grapes (wine) and other fruits, for example citrus, and vegetables, and increasingly in recent years, almond plantations.

The Water Plan enacted in 2012 through federal legislation is a far-reaching and basin-wide initiative (<https://www.mdba.gov.au/water-management/basin-plan> accessed 26 May 2025) that has implications for many farming enterprises as well as the communities depending directly and indirectly on the agricultural industries. The decision to re-allocate water away from irrigation towards river and wetland restoration has implications for agriculture and the wider social settings.

b) Protecting wetlands and mitigating pressure/impact on wetlands

One of the key mechanisms for maintaining or restoring wetlands is the use of environmental flows to ensure that key sites and species have sufficient water across different stages of their life cycles, such as for feeding or breeding in specific habitats. High profile targets have included waterbirds, in particular colonial nesting species, and native fish, as well as water quality (Gawne et al. 2019; Brookes et al. 2023). The implementation of environmental flows has been accompanied by a large investment in hydrological and ecological monitoring and research to both inform the environmental water allocations, as well as assess the ecological responses and outcomes. This information can be used to adaptively respond and ensure the best outcomes are achieved with the water available (Gawne et al. 2021). In places where it can prove difficult to flood specific areas with environmental flows a range of engineering works have been established to help re-distribute flows (Figure 2). These works have been difficult to implement, and questions have been raised about their effectiveness and costs (Pittock and Finlayson 2011; Colloff et al. 2024). Other measures addressing issues associated with water quality, invasive species, and the impacts of water regulation structures have also been implemented or are under consideration (Baumgartner et al. 2020).



Figure 2. Murray Darling Basin, with water management infrastructure on rivers (top left left and right) and in lakes (weir in Lake Brewster (bottom left). (© Max Finlayson)

Understanding the ecological processes and biological responses to allocations of water for environmental purposes is a key issue given the variability in climate and conditions across the Basin, the complexity of dealing with a changing climate, and other ecological pressures, such as the presence of invasive species. An interim evaluation of the Basin Plan provided an economic, social as well as ecological assessment of the outcomes from water management actions, although most monitoring in the Basin considered only biophysical variables (Gawne et al. 2017). In terms of addressing the condition of the Wetlands of International Importance in the Basin it is necessary to consider the ecosystem services, an aspect of the outcomes that could warrant further attention and identify benefits from specified water management activities (Kahan et al. 2020). The biophysical investigations have reported favourable ecological responses, such as the breeding and recovery of some fish populations (Koehn et al. 2019), but are also set against the backdrop of ecological disasters such as the unprecedented fish kills that have occurred in the lower reaches of the Darling River in recent years (Sheldon et al. 2024; Koehn et al. 2021). An analysis of agreed environmental water requirements for sites along the rivers in the Basin determined that more than two-thirds of those assessed had not been achieved (Sheldon et al. 2024). Amongst those that had been achieved were those for the Narran Lakes and Gwydir wetlands, upstream of the eight Wetlands of International Importance in the Basin. However, none of the environmental water requirements for overbank flows along the Murray River had been achieved, contributing to the poor condition of the wetland and floodplain ecosystems across a significant portion of the Basin. Colloff et al. (2024) assessed the implementation of the Plan by synthesising publicly available data and recommended that a more comprehensive, Basin-wide monitoring and reporting framework could be implemented to aid assessment of progress on implementation of the basin plan.

c) Supporting rural livelihoods, equity, and social well-being

The implementation of the Plan has been accompanied by a vocal and continuing social and political commentary about the mechanisms, perceived outcomes, benefits, and costs (Alexandra 2018; Ward et al. 2024)). The water market has been effective in purchasing water from willing sellers for environmental purposes. It has also led to backlash from rural communities who feel that the removal of water for agricultural production from specific regions has resulted in adverse social-economic outcomes (Williams 2017). This has resulted in further socio-economic analyses, complete with the need to address and separate compounding issues affecting the social and economic settings of the farming communities (Ward et al. 2022; Wheeler et al. 2024).

The implementation of the Plan has been accompanied by ongoing consultation with stakeholders and politicised decision making around the social-economic impacts on the farming communities affected by the reallocation of water away from irrigated agriculture. In particular, the use of a market mechanism for purchasing water for environmental purposes has been criticised as not sufficiently taking into account the wider social and economic impacts on local communities. The proposed alternative of making more efficient use of water and engineering structures to spread water across the floodplains has however, not recovered sufficient volumes of water (Colloff et al. 2024). These mechanisms will be subject to review in 2026.

In addition to addressing the socio-economic issues around changes in agriculture there has been a concerted effort by Indigenous Peoples across the Basin to obtain benefits for their communities from the restructuring of the water management regimes (Jackson et al. 2021). While the engagement of Indigenous People in land and water matters has improved there is still a need to confront the legacies of colonisation and exclusion from the water sector. Notwithstanding signs of progress there are unmet needs and unresolved claims for recognition of cultural flows framed as flows of water delivered to particular sites for cultural uses, as well as water entitlements, or a property right to water (Davies et al. 2023).



Figure 3. Wetlands in the Murray Darling Basin, with dry creek bed (left) and a sedge marsh and forested wetlands (right). (© Max Finlayson)

d) Building resilience in people, communities, and ecosystems

Implementation of the water plan has been undertaken with the resilience of both the people and communities in mind, although the manner in which this is seen varies greatly with some people feeling disadvantaged or alienated. In part this can be attributed to the outcomes of working through a water market that can result in individual decisions to sell water having adverse outcomes on others in the community. This has been addressed to some extent by limiting water purchases by the

governmental water holders if they have adverse social or economic outcomes, although such decisions seem influenced by how political decisions have affected implementation of all parts of the plan. Some of the actions that will directly affect private property have been delayed in response, but equally they seem destined to occur even if delayed somewhat. Foremost amongst these are decisions being taken about how to increase flows in parts of the rivers where they are currently constrained by physical factors or private property rights (Kahan et al. 2020). Addressing these could see compensatory measures being offered where damage or limits on usage occur.

The resilience of the communities across the basin is also influenced by the particular geographic features and the agricultural practices that are possible, or the ability to adapt and adjust such practices. This has seen changes in the dominance of specific crops in some areas, such as for growing cotton on an annual basis, or the establishment of nut plantations. These are decisions being made by individual agricultural enterprises in response to access to water, including by purchasing or selling water in response to market prices, or from climate variability. The swing from flooding to drought conditions is a major factor behind agricultural decision-making as well as for allocating environmental flows for ecosystem purposes. The ability of individuals to make such decisions has been supported by a governmental investment in meteorological data and forecasting as well as in measuring water flows.

While climate change responses were not featured early in the implementation of the water plan (Pittock and Finlayson 2011) they are now receiving a lot of attention (Alexandra 2018; Whetton and Chiew 2021). Efforts to support adaptation measures have increased with an emphasis on identifying viable options under the highly variable climate with more likely occurrence of extreme events (Lukasiewicz et al. 2016).

e) Responsible and effective governance and institutions

The water plan for the Basin is supported by specific federal legislation and agreements with the state governments. The federal government Water Act (2006) was based on the ability of the federal government to legislate on international responsibilities and activities under environmental agreements such as the Convention on Wetlands. The Water Plan promulgated in November 2012 and due for review in 2026 is the key mechanism for achieving environmental outcomes amidst the social and economic settings across the Basin, characterized by substantive agricultural investments with social outcomes that extend across multiple communities. This involves agreements between the federal and state governments, being aware that amongst the latter the particular details and emphases differ. The limited role of local government in the legislated frameworks and social-environmental practice is another facet of the governance and management arrangements that has received attention, including disagreement and disillusionment by local communities.

The environmental outcomes from the reallocation of water across the Basin are clearly outlined at a policy level, and not unexpectedly, will require a substantial and ongoing effort to achieve. This includes effective engagement with communities, a process that was heavily criticised at the outset of the legislative and planning processes. It also requires investment in the science and engineering to ensure the ecological outcomes are achieved, and are sustained under contested social-political settings and a variable climate with warming temperatures, generally declining rainfall, shifts in seasonal patterns, and an increased likelihood of extreme events (floods and droughts).

Legislative frameworks are in place – there is an investment in the science and engineering associated with water management – a water trading system is established as a key economic instrument – lessons from previous missteps are being addressed, such as those around the form of communicating with local communities – and climate change has been factored into the mix. The monitoring and management systems in place are within the context provided by an adaptive management framework (Alexandra 2018; Webb et al. 2018), and recognised to be long-term processes. There are

ecological “surprises”, including disastrous fish kills (Koehn et al. 2021) and algal blooms (Beavis et al. 2023), and critiques by scientists and communities (Ryan et al. 2021).

The governmental agency responsible for implementing the Plan has responded with various communication and consultation mechanisms in order to keep affected communities informed about progress with implementation and to receive advice on further steps. This includes reaching out to communities in their towns and on their farming properties, as well as through internet-based information sessions. As several major parts of the Plan have yet to be achieved these processes are essential especially in situations where the communities are cynical or have deep-rooted mistrust of governmental agencies or research organisations (Ward et al. 2022). Extension services or communication with stakeholders is seen as a key component of the water planning as it seeks to deliver the expected outcomes and to implement measures that still need to be addressed. An example is the intention to increase the flows along the rivers in order to deliver more water for downstream purposes – this is expected to flood both public and private land and infrastructure with disruptions to access or use of some land, and damage to infrastructure (Pittock et al. 2023). Compensatory mechanisms have been proposed, and are likely to be needed, but have been resisted by some landholders. Among the many reasons for this are long held views around water management and allocations as well as ongoing discontent or frustration when dealing with governmental processes, leading to distrust and anger, and at times a sense of disempowerment in the face of decision-making that is seen to be at odds with their expectations for a future in farming (Ward et al. 2022).

Conclusions

The ongoing efforts to balance the restoration of the river and wetlands across the basin and support ongoing agricultural activities and their wider social and economic benefits is tied in with the water plan for the basin. The reallocation of water to enable the implementation of environmental flows for environmental purposes is a key component of the plan. While environmental flows are the main mechanisms for ecosystem outcomes there has also been an economic investment in infrastructure to assist the distribution of water for environmental purposes. The successful implementation of environmental flows is supported by an investment in monitoring and research to provide information on the effectiveness of and further decisions about future flows. The water plan is supported by a water market to enable trade in water allocations and to provide opportunities for agricultural enterprises to invest in or divest their water allocations, with an increased emphasis on engaging stakeholders, especially given that the implementation of the plan is still contentious with major social and economic implications.

Key references

- ABS, ABARE, BRS (2009) Socio-economic context for the Murray–Darling Basin – descriptive report. MDBA publication no. 34/09. Murray–Darling Basin Authority, Canberra.
- Alexandra J (2018) Evolving governance and contested water reforms in Australia’s Murray Darling Basin. *Water* **10**, 113. <https://doi.org/10.3390/w10020113>
- Baumgartner LJ, Gell P, Thiem JD, Finlayson CM, Ning N (2020) Complementary measures to assist with environmental watering programs in the Murray-Darling River system, Australia. *River Research and Applications* **36**, 645–655. <https://doi.org/10.1002/rra.3438>
- Beavis SG, Wong VN, Mosley LM, Baldwin DS, Latimer JO, Lane P, Lal A (2023) Water quality risks in the Murray-Darling basin. *Australasian Journal of Water Resources* **27**, 85–102. <https://doi.org/10.1080/13241583.2022.2163475>

- Brookes JD, Busch B, Cassey P, Chilton D, Dittmann S, et al. (2023) How well is the Basin Plan meeting its objectives? From the perspective of the Coorong, a sentinel of change in the Murray-Darling Basin. *Australasian Journal of Water Resources* **27**, 223–240. <https://doi.org/10.1080/13241583.2023.2241161>
- Chiew FH, Vaze J, Viney NR, Perraud JM, Teng J, et al. (2008) Estimation of impact of climate change and development on runoff across the Murray-Darling Basin. In *Proceedings of Water Down Under 2008*. Engineers Australia; Causal Productions. <https://search.informit.org/doi/10.3316/informit.591404228758299>
- Colloff MJ, Lanyon K, Pittock J, Costanza-van den Belt M, Wheeler S, et al. (2024) Murky waters running clearer? Monitoring, reporting and evaluation of the state of the Murray–Darling Basin after more than three decades of policy reform. *Marine and Freshwater Research* **75**, <https://doi.org/10.1071/MF24193>.
- Connell D (2007) *Water Politics in the Murray-Darling Basin*. The Federation Press, Annadale, Australia.
- Connell D, Grafton RQ (2011) *Basin Futures Water reform in the Murray-Darling Basin*. ANU E Press, Canberra.
- Davies S, Marshall GR, Ridges M (2023) A property rights schema for cultural flows in the Murray Darling Basin, Australia. *Australasian Journal of Environmental Management* **30**, 393–415. <https://doi.org/10.1080/14486563.2023.2281562>
- Gawne B, Ryan KA, Coleman M, Meehan A, Davies PE, et al. (2017) In: *Monitoring, evaluation, and adaptive management in the Murray–Darling Basin*. In [Murray-Darling Basin, Australia: Its Future Management](#). Hart BT, Bond NR, Byron N, Pollino CA, Stewardson MJ (eds). pp. 227–249. Elsevier.
- Gawne B, Hale J, Stewardson MJ, Webb JA, Ryder DS, et al. (2019) Monitoring of environmental flow outcomes in a large river basin: The Commonwealth Environmental Water Holder's long-term intervention in the Murray–Darling Basin, Australia. *River Research and Applications* **36**, 630–644. <https://doi.org/10.1002/rra.3504>
- Gawne B, Ryan KA, Coleman M, Meehan A, Davies PE, et al. (2021) Monitoring, evaluation, and adaptive management in the Murray–Darling Basin. In: *Murray-Darling Basin, Australia*. Hart BT et al. (eds). Elsevier. pp. 227–249. <https://doi.org/10.1016/B978-0-12-818152-2.00011-5>
- Hart BT (2015) The Australian Murray–Darling Basin Plan: challenges in its implementation (part 1). *International Journal of Water Resources Development* **32**, 819–834. <https://doi.org/10.1080/07900627.2015.1083847>
- Holland JE, Luck GW, Finlayson CM (2015) Threats to food production and water quality in the Murray-Darling Basin of Australia. *Ecosystem Services* **12**, 55–70. <https://doi.org/10.1016/j.ecoser.2015.02.008>
- Jackson S, Woods R, Hooper F (2021) Empowering First Nations in the governance and management of the Murray–Darling Basin. In: *Murray-Darling Basin, Australia*. Hart BT, Bond NR, Byron N, Pollino CA, Stewardson MJ (eds). Elsevier. pp. 313–338. <https://doi.org/10.1016/B978-0-12-818152-2.00015-2>
- Kahan G, Colloff M, Pittock J (2020) Using an ecosystem services approach to re-frame the management of flow constraints in a major regulated river basin. *Australasian Journal of Water Resources* **25**, 222–233. <https://doi.org/10.1080/13241583.2020.1832723>
- Koehn JD, Balcombe SR, Zampatti BP (2019) Fish and flow management in the Murray–Darling Basin: directions for research. *Ecological Management and Restoration* **20**, 142–150. <https://doi.org/10.1111/emr.12358>
- Koehn JD (2021) Key steps to improve the assessment, evaluation and management of fish kills: lessons from the Murray–Darling River system, Australia. *Marine and Freshwater Research* **73**, 269–281.
- Kingsford RT, Walker KF, Lester RE, Young WJ, Fairweather PG, et al. (2011) A Ramsar wetland in crisis – the Coorong, Lower Lakes and Murray Mouth, Australia. *Marine and Freshwater Research* **62**, 255–265. <https://doi.org/10.1071/MF09315>

- Lukasiewicz A, Pittock J, Finlayson CM (2016) Are we adapting to climate change? An adaptation assessment framework for managing freshwater ecosystems. *Climatic Change* **138**, 641–654. <https://DOI.10.1007/s10584-016-1755-5>
- Neave I, McLeod A, Raisin G, Swirepik J (2015) Managing water in the Murray-Darling Basin under a variable and changing climate. *Water: Journal of the Australian Water Association* **42**, 102–107. <https://search.informit.org/doi/10.3316/informit.269194666182946>
- Mallawaarachchi T, Auricht C, Loch A, Adamson D, Quiggin J (2020) Water allocation in Australia's Murray–Darling Basin: Managing change under heightened uncertainty. *Economic Analysis and Policy* **66**, 345–369. <https://doi.org/10.1016/j.eap.2020.01.001>.
- Pittock J, Finlayson CM (2011) Australia's Murray Darling Basin: freshwater ecosystem conservation options in an era of climate change. *Marine and Freshwater Research* **62**, 232–243. <http://dx.doi.org/10.1071/MF09319>
- Pittock J, Corbett S, Colloff MJ, Wyrwoll P, Alexandra J, et al. (2023) A review of the risks to shared water resources in the Murray–Darling Basin. *Australasian Journal of Water Resources* **27**, 1–17. <https://doi.org/10.1080/13241583.2023.2190493>
- Ryan A, Colloff MJ, Pittock J (2021) Flow to nowhere: the disconnect between environmental watering and the conservation of threatened species in the Murray–Darling Basin, Australia. *Marine and Freshwater Research* **72**, 1408–1429. <https://doi.org/10.1071/MF21057>
- Sheldon F, Eytan R, Steinfeld C, Colloff MJ, Moggridge B, et al. (2024) Are environmental water requirements being met in the Murray–Darling Basin, Australia? *Marine and Freshwater Research* **75**, MF23172. <https://doi.org/10.1071/MF23172>
- van Dam AA, Robertson H, Prieler R, Dubey A, Finlayson CM (2025) Recognizing diversity in wetlands and farming systems to support sustainable agriculture and conserve wetlands. *Marine and Freshwater Research* **76**, MF24017. <https://doi.org/10.1071/MF24017>
- Ward JA, Finlayson C, Vanderzee M (2024) Managing biodiversity on private land: Directions for collaboration through reconciliation ecology. *Ecological Management and Restoration* **25**, 85–92. <https://doi.org/10.1111/emr.12606>
- Ward W, Bond J, Burge L, Conallin J, Finlayson M, et al. (2022) Biodiversity on private land: Lessons from the Mid-Murray Valley in South-eastern Australia. *Ecological Management and Restoration* **23**, 175–183. <https://doi.org/10.1111/emr.12560>
- Webb JA, Watts RJ, Allan C et al (2018) Adaptive Management of Environmental Flows. *Environmental Management* **61**, 339–346. <https://doi.org/10.1007/s00267-017-0981-6>
- Wheeler SA, Xu Y, Zuo A (2024) Developing an economic quality assessment framework and applying it to water economic studies in the Murray-Darling Basin. *Environmental Science & Policy* **152**, 103654. <https://doi.org/10.1016/j.envsci.2023.103654>
- Whetton P, Chiew F (2021) Climate change in the Murray–Darling Basin. In: Murray-Darling Basin, Australia: Its Future Management. Hart BT, et al. (eds). pp. 253–274. Elsevier. <https://doi.org/10.1016/B978-0-12-818152-2.00012-7>
- Williams J (2017) Water reform in the Murray-Darling Basin: a challenge in complexity in balancing social, economic and environmental perspectives. *Journal and Proceedings of the Royal Society of New South Wales* **150**, 68–92. <https://search.informit.org/doi/10.3316/informit.075847584027595>