TJF RESEARCH BRIEF

Wetland Management Techniques for Sustainable Agriculture

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Executive Summary

Wetlands cover large areas of land and can support food production, especially in countries like Indonesia. However, these lands are often classified as sub-optimal because they have high water tables, acidic soils, and unstable soil structures. In peatland, agricultural drainage can also release stored carbon and contribute to greenhouse gas emissions. Therefore, wetland agriculture requires specialized management approaches that address both productivity and environmental protection.

Water control is the most critical factor in wetland agriculture. Techniques such as drainage canals, irrigation systems, sluice gates, and polder systems help regulate water levels to prevent flooding. Soil management practices are also necessary to overcome soil acidity and low fertility.

Techniques such as liming to increase soil pH, applying organic fertilizers, and raised-bed farming to improve root aeration can significantly improve crop productivity while maintaining soil health.

Choosing crops adapted to wet conditions is key to successful wetland agriculture. Crops such as rice perform well in a wetland environment. In addition, integrated farming systems that can combine crop production, aquaculture, and livestock can improve resource efficiency and farm income. For example, rice-fish farming systems allow fish water to fertilize rice crops while producing an additional food source. This approach potentially supports both economic resilience for farmers and the sustainable use of wetland ecosystems.

Key Findings

1. Wetlands are a major land resource for future food production, especially where upland farmland is limited.

2. Wetland agriculture requires specialized management due to flooding, acidic soils, and unstable land conditions.

3. Water control systems (e.g., drainage, sluice gates, polder) are key to regulating water levels.

4. Soil management (liming, organic inputs, raised beds) improves fertility and nutrient availability.

5. Selecting flood-tolerant crops, especially rice, is essential for stable productivity.

6. Integrated systems (e.g., rice–fish) enhance efficiency and diversify food production.

Introduction

Wetlands are increasingly recognized as strategic landscapes and assets for addressing global food security challenges amid climate change pressures, population growth, and the increasing scarcity of fertile upland farmland (Regmi & Gheewala, 2025). Characterized by saturated soils and persistently high water levels (Song et al., 2023), wetlands encompass a diverse range ecosystems, including peatlands, swamps, and tidal wetlands. Wetlands are important for its potential in agricultural production and how it contributes on food consumption directly and indirectly (Figure 1). In many regions of the world, wetlands represent large areas of land that could support food production if managed appropriately.

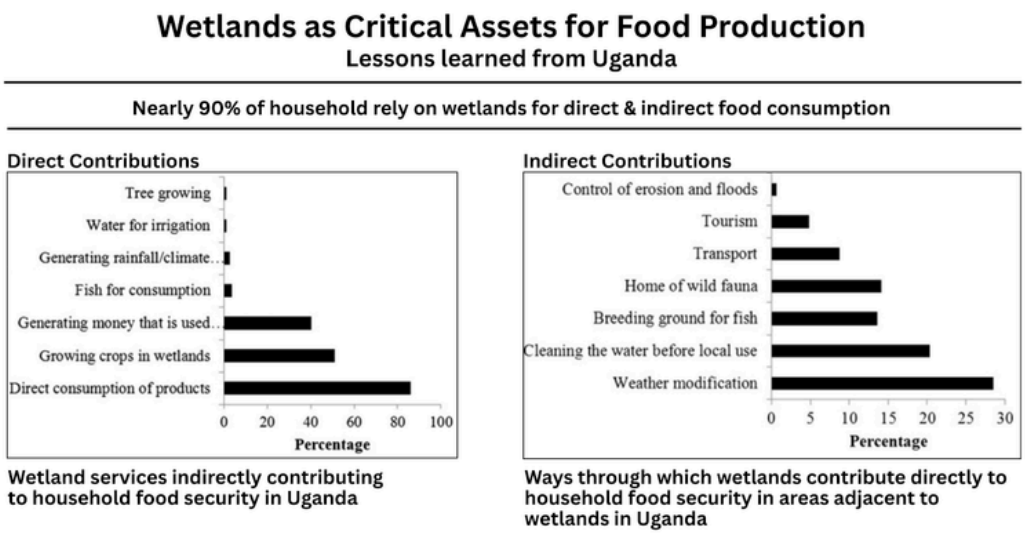

Figure 1. Wetlands as critical landscapes for food production and system resilience
Source: Turyahabwe et al. (2024)

In countries such as Indonesia, wetlands cover extensive areas and have become increasingly important for agriculture due to the growing demand for food and the limited availability of fertile upland farmland areas (Verhoeven et al., 2010). In fact, wetlands in Indonesia covers approximately 21% of the national land area, which is equivalent to 39.6 million hectares (Margono et al., 2014), these wetlands area mostly distributed in main islands such as Sumatera, Kalimantan, and Papua (Figure 2). Many wetland areas are considered sub-optimal lands because they have natural constraints such as flooding, acidic soils, and unstable soil structure. However, with appropriate management techniques, wetlands can be transformed into productive agricultural landscapes.

Wetlands cover approximately of the total national land area **21%**

Equivalent to **39.6** million hectares.

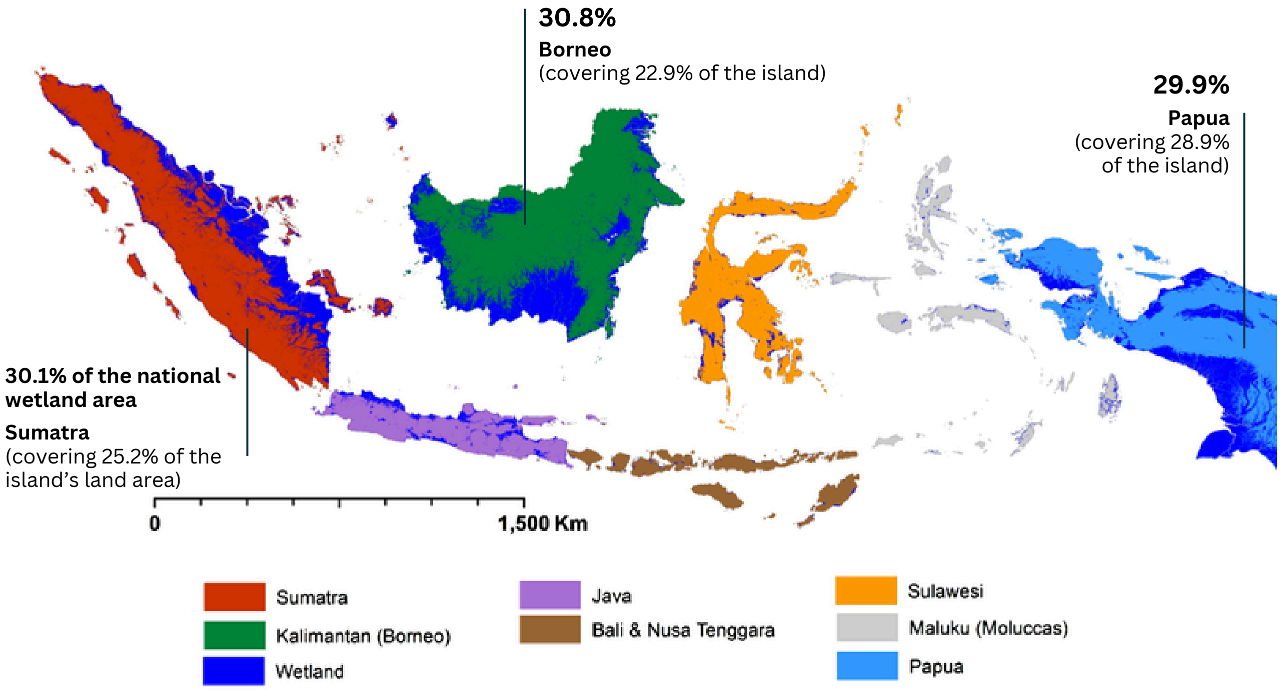

Figure 2. The Distribution of wetlands in Indonesia
Source: Margono et al. (2024)

Wetland management for agriculture requires a careful balance between increasing agricultural productivity and protecting the natural ecosystem. Poorly managed wetland conversion can lead to environmental problems such as soil degradation, subsidence, and greenhouse gas emissions (Belle et al., 2018). Therefore, sustainable wetland management techniques are essential to ensure that agricultural development does not damage the ecological functions of wetlands. This brief discusses the characteristics of wetlands, the challenges of farming in wetland environments, and the key management techniques used to support sustainable agriculture in these areas.

Characteristics and Challenges of Wetland Agriculture

Despite their agricultural potential, wetland farming faces significant operational constraints due to challenging soil and hydrological conditions (Figure 3). Wetlands have several physical and chemical characteristics that make agricultural development considerably more complex compared with upland areas. One of the main characteristics is the high water table, where water remains close to or above the soil surface for long periods. This condition can cause waterlogging, which limits oxygen availability for plant roots and reduces crop growth (He et al., 2025).

Another key characteristic is the unstable soil structure typical of many wetland environments. Peatlands, in particular, contain large amounts of organic matter and water, resulting in soils with low bearing capacity and highly susceptible to compression. Consequently, agricultural practices such as land preparation and transportation, including the use of agricultural machinery, become more difficult to execute.

Wetland soils also present significant chemical constraints. Peat soils are typically acidic, with low pH levels that restrict nutrient availability for plants.

Meanwhile, in tidal wetlands, saltwater intrusion can increase soil salinity, which further limits crop growth. These constraints contribute to lower productivity, higher production costs, and a greater risk of crop failure than in conventional farming areas.

Figure 3. Characteristics of wetlands that are always flooded and rich in organic material
Source: TJF Documentation (2023)

In addition to challenging soil and hydrological conditions, wetlands are highly sensitive ecosystems. Improper land management practices, such as excessive drainage or burning, can trigger peat oxidation and land subsidence. These processes release stored carbon into the atmosphere and contribute to climate change (Ribeiro et al., 2021). Because of these challenges, wetland agriculture requires specialized management techniques that integrate water control, soil improvement, and environmental protection.

Water Management Techniques

Water management is the most critical aspect of wetland agriculture. Since wetlands naturally contain large amounts of water, effective regulation of water levels is essential to create suitable conditions for crop production. One widely applied technique is the application of drainage canals. Drainage canals allow excess water to flow out of agricultural fields during periods of heavy rainfall, preventing prolonged flooding and maintaining an appropriate water level for the land itself and for crop growth.

This technique has been successfully implemented in Indonesia, specifically in Indragiri Hilir Regency, Riau Province, through Water Management Trinity (WMT), or "*Trio Tata Air*" in Indonesian (Figure 4). The WMT integrates water retention, controlled drainage, and regulated distribution to balance agricultural needs and ecological conditions. The WMT was developed as a context-specific approach for improving wetland agricultural practices in peat-dominated landscapes (Fawzi et al., 2024).

Another important technique is the use of water control structures, such as water gates and pumping systems, specifically in the agricultural field. These structures regulate the movement of water between canals and agricultural fields. It is very suitable for farmers to adjust water levels depending on crop requirements and seasonal conditions.

In some countries, an advanced water management system called the polder system is used. The polder system involves constructing dikes around low-lying land

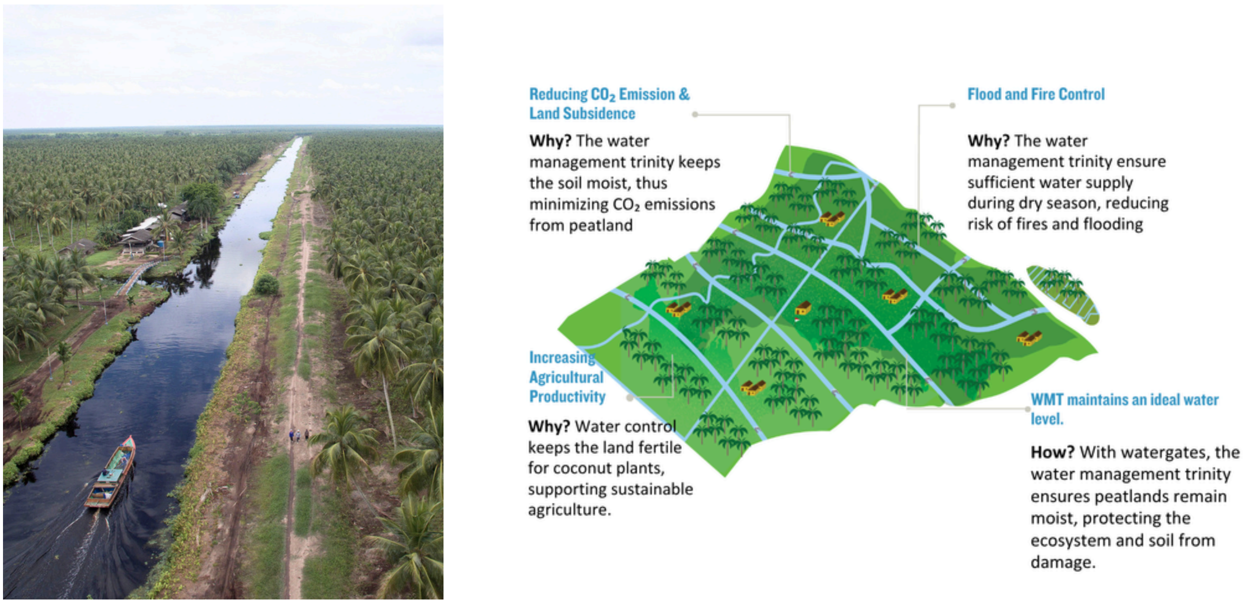

Figure 4. *Trio Tata Air,* the Water Management Trinity in Indragiri Hilir
Source: TJF Documentation (2021)

using pumps to remove excess water. This technique has been successfully implemented in the Netherlands, where large areas of land have been reclaimed from wetlands and the sea for agricultural use (Renes et al., 2011). Proper water management not only improves crop growth but also helps protect wetland ecosystems from environmental degradation.

In peatlands, maintaining stable water levels can reduce peat decomposition and minimize the risk of land subsidence. Effective water management provides the foundation for agricultural practices in wetlands. However, regulating water levels alone is not sufficient; it must be complemented by proper soil management practices to overcome the natural limitations of wetland soils.

Soil Management and Improvement

Soil management is another essential aspect of sustainable wetland agriculture. Wetland soils are frequently acidic and low in available nutrients. In many wetland areas, soil pH can be very low, sometimes below 4.5, due to the presence of organic acids or the oxidation of sulfide minerals such as pyrite. When soils become highly acidic, toxic elements such as aluminum and iron become more soluble and can damage plant roots, while essential nutrients like phosphorus become less available to crops (Goulding, 2016). These conditions limit plant growth and reduce agricultural productivity, making soil improvement a necessary step in wetland farming.

One of the most widely used methods to address soil acidity is liming, which involves applying agricultural lime to increase soil pH (Figure 5). Liming helps neutralize soil acidity and improves the availability of essential nutrients for crops (Goulding, 2016). This process is carried out by applying calcium- or magnesium-containing materials, such as dolomite, to raise soil pH to a more suitable level for plant growth, typically around pH 6 or higher.

In practice, liming is usually conducted during the early stage of land preparation, approximately two to four weeks before planting, to allow sufficient time for the materials to react with the soil. Lime is generally spread evenly across the field and then mixed into the topsoil by plowing to maximize its effectiveness. Application rates vary depending on soil conditions but typically range from 1 to 4 tons per hectare in wetland agricultural systems.

Figure 5. Dolomite Application into Soil
Source: TJF Documentation (2026)

Another important step is applying organic fertilizer, such as compost, manure, or crop residues. Organic matter amendments improve soil structure, increase nutrient availability, and promote beneficial microbial activity in the soil (Hatano et al., 2024). In addition, the raised bed technique is commonly used by farmers to enhance drainage in wetland fields (Figure 6). Based on what farmers said in the field, this technique involves planting crops on elevated soil ridges, allowing excess water to drain away from plant roots and improving oxygen availability.

Figure 6. Raised Bed Technique
Source: TJF Documentation (2026)

Once soil conditions improve, the focus can shift to selecting appropriate crops and developing integrated farming systems that optimize the productivity and sustainability of wetland agriculture. These step-by-step soil management practices are summarized in Figure 7, providing a practical overview for implementation in wetland contexts.

Key Steps in Wetland Soil Management

1. **Soil Assessment**
   Identify soil pH, acidity, and nutrient limitations sment.
2. **Water Control**
   Regulate water levels to prevent fooding and soil axidation.
3. **Liming**
   Apply lime to increasi pH and reduce soil acidity.
4. **Organic Input**
   Add compost or manure to improve soil structure and fertility.
5. **Raised Beds**
   Improve drainage and root aeration through elevated planting.
6. **Cropping System Optimization**
   Select suitable crops and integrate systems for productivity.

Figure 7. Key Steps in Wetland Soil Management

Crop Selection and Integrated Agricultural Systems

Crop selection is a critical determinant of success in wetland agriculture practices; certain crops are naturally adapted to wet conditions and can tolerate waterlogged soils. One notable example is rice, which is one of the most common crops grown in wetlands. Rice plants are well adapted to flooded environments and have been cultivated in wetland ecosystems in many Asian countries (Nath et al., 2017).

Selecting rice varieties suitable for wetlands is important. In Indonesia, several rice varieties have been developed specifically for wetland environments, for example, Inpari 30, which is a flood-tolerant variety that can survive well in such conditions (Suparwoto et al., 2017), and others such as Inpara 3 and Inpara 5, which are tolerant to fluctuating water levels and moderately acidic soil (Koesrini et al., 2017). Other crops, such as taro, sago, and some vegetable varieties, can also grow in wetland environments. Choosing suitable crop varieties that tolerate wet conditions helps farmers achieve stable yields.

Beyond crop selection, wetland agriculture can be further optimized through an integrated agricultural system that combines multiple activities, such as crop production, aquaculture, and livestock farming, within a single, coordinated framework. For example, rice fields can be combined with fish farming, where fish are raised in flooded rice paddies, which in Indonesia is known as *"mina padi"* (Figure 8). This practice improves resource efficiency because nutrients from fish waste can fertilize the rice plants.

Figure 8. *Mina Padi* Practice
Source: Ambari (2019)

Integrated farming systems also contribute to greater farm income diversification and reduced risk of total production failure.

Summary and Conclusion

Wetlands present unique opportunities and challenges for agricultural development. Their high water levels, soft soils, and chemical limitations make farming more complex than in upland areas. However, with appropriate management techniques, wetlands can become productive agricultural landscapes.

Effective wetland management for agriculture requires an integrated approach that includes water control, soil improvement, and crop selection. Techniques such as drainage canal construction, liming, raised-bed farming, and integrated farming systems can help overcome many limitations associated with wetland characteristics. At the same time, sustainable management is essential for protecting the wetland's ecological functions. Practices such as controlled drainage can help to ensure that agricultural activities do not damage these valuable ecosystems.

In conclusion, with growing pressures on global food systems, wetlands offer an important opportunity to expand food production while maintaining environmental sustainability. Strengthening sustainable wetland management practices will therefore be essential to support both agricultural productivity and ecosystem resilience.

Reference

Ambari, M. (2019, January 28). *Suksesnya minapadi di Indonesia, jadi rujukan ke seluruh dunia. Mongabay Indonesia*. https://mongabay.co.id/2019/01/28/sukses nya-minapadi-di-indonesia-jadi-rujukan-ke-seluruh-dunia/

Belle, J. A., Collins, N., & Jordaan, A. (2018). *Managing wetlands for disaster risk reduction: A case study of the eastern Free State, South Africa.* Jamba (Potchefstroom, South Africa), 10(1), 400. https://doi.org/10.4102/jamba.v10i1.40

Fawzi, N. I., Sumawinata, B., Suwardi, Rahmasary, A. N., Qurani, I. Z., Naufaldary, R. G., Nabillah, R., Palunggono, H. B., & Mulyanto, B. (2024). *Integrated water management practice in tropical peatland agriculture has low carbon emissions and subsidence rates*. Heliyon, 10(2), e26661. https://doi.org/10.1016/j.heliyon.2024.e26 661

Goulding K. W. (2016). S*oil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom. Soil use and management, 32(3), 390–399.* https://doi.org/10.1111/sum.12270

Hatano, R., Mukumbuta, I., & Shimizu, M. (2024). *Soil Health Intensification through Strengthening Soil Structure Improves Soil Carbon Sequestration.* Agriculture, 14(8), 1290. https://doi.org/10.3390/agriculture140812 90

He, H., Li, X., & Li, T. (2025). *The Sustainable Development of Wetlands and Agriculture: A Literature Review.* Agronomy, 15(3), 746. https://doi.org/10.3390/agronomy1503074 6

Koesrini, Kahirullah I, Saleh M, Rosa HO. (2017). *Keragaan tanaman padi dan palawija di lahan rawa. Dalam Masganti et al. (Eds.).* Agroekologi Rawa. IAARD Press. Jakarta. Hlm 143-164.

Margono, B. A., Bwangoy, J.-R. B., Potapov, P. V., & Hansen, M. C. (2014). *Mapping wetlands in Indonesia using Landsat and PALSAR data-sets and derived topographical indices.* Geo-spatial Information Science, 17(1), 60–71. https://doi.org/10.1080/10095020.2014.89 8560

Nath, A. J., & Lal, R. (2017). *Managing tropical wetlands for advancing global rice production: Implications for land-use management.* Land Use Policy, 68, 681–685. https://doi.org/10.1016/j.landusepol.2017. 08.026

Regmi, S., & Gheewala, S. H. (2025). *Scaling up nature-based solutions for food security and climate resilience in wetlands: Typologies, barriers and opportunities.* Journal for Nature Conservation, 88, 127062. https://doi.org/10.1016/j.jnc.2025.127062

Renes, H., & Piastra, S. (2011). *Polders and Politics: New Agricultural Landscapes in Italian and Dutch Wetlands, 1920s to 1950s.* Landscapes, 12(1), 24–41. https://doi.org/10.1179/lan.2011.12.1.24

Ribeiro, K., Pacheco, F. S., Ferreira, J. W., de Sousa-Neto, E. R., Hastie, A., Krieger Filho, G. C., Alvalá, P. C., Forti, M. C., & Ometto, J. P. (2021). *Tropical peatlands and their contribution to the global carbon cycle and climate change.* Global change biology, 27(3), 489–505. https://doi.org/10.1111/gcb.15408

Song, J., Zhang, R., Wang, Y., & Huang, J. (2023). *Evolution Characteristics of Wetland Landscape Pattern and Its Impact on Carbon Sequestration in Wuhan from 2000 to 2020.* Land, 12(3), 582. https://doi.org/10.3390/land12030582

Suparwoto, Waluyo, dan Sasmita P. (2017). *Produksi dan usahatani padi varietas unggul baru di lahan rawa lebak Kabupaten Banyuasin Sumatera Selatan.* Jurnal Penelitian Pertanian Terapan, 17 (3): 176-180.

Turyahabwe, R., Andama, E., Mulabbi, A., & Nakiyemba, A. (2024). *Understanding the nexus between traditional brick-making, biophysical and socio-economic environment of Goma Division, Mukono Municipality, Central Uganda.* Journal of Degraded and Mining Lands Management, 11(4), 6367–6378. https://doi.org/10.15243/jdmlm.2024.114.6367

Verhoeven, J. T., & Setter, T. L. (2010). *Agricultural use of wetlands: opportunities and limitations.* Annals of botany, 105(1), 155–163. https://doi.org/10.1093/aob/mcp172

About Tay Juhana Foundation

Tay Juhana Foundation (TJF) is a nonprofit organization dedicated to promote the advocacy of the conversion and cultivation of suboptimal lands into productive lands, through the most environmentally, economically, and socially sustainable manner.

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