Coconut-based Agroforestry-Paludiculture to Improve Peatlands Sustainability and Food Security

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Summary:

- Implementing coconut in agroforestry-paludiculture systems has expanded beyond peat restoration to include both ecological and economic benefits.
- Viable intercropping crops such as areca nut, cassava, banana, pineapple, and liberica coffee have increased income and improved soil conditions by increasing biodiversity and cover crops.
- Integrating paludiculture with agroforestry could offer a sustainable solution to food insecurity and ecological challenges in peatland areas.

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Introduction

Increasing global populations and the depletion of agricultural lands pose significant challenges for the sustainability of food production and supply systems. Moreover, the quantity and quality of agricultural land are diminishing due to water scarcity and climate variability. These challenges threaten not only global food security but also the livelihoods of rural communities dependent on agriculture. In 2020, food production in Indonesia was insufficient to meet the needs of its 270 million inhabitants. With the population projected to reach 311 million by 2050, enhancing food security is essential for maintaining stability and the welfare of its people. Concurrently, as the population and its food requirements increase, arable land is becoming increasingly scarce.

One potential solution to boost food production is the utilization of peatlands, which have been targeted for agricultural and plantation expansion. Traditional use of peatlands for food production by indigenous communities has been ongoing for centuries. During the colonial era, the Dayak people of Kalimantan and the Malay people of Sumatra utilized peatlands for small-scale farming, sago planting, collecting non-timber products, and fishing (Mizuno, 2021). In Riau, local communities have long cultivated sago and purun (*Lepironia articulata*), plants native to swampy areas. These communities have been cultivating and consuming sago since the colonial era. Additionally, weaving purun mats has been a generational craft among the women in the region, providing income through market sales (Noor, 2019). The community benefits from harvesting these naturally suited crops in peatlands. In Kalimantan, peatlands have also traditionally been used for agriculture to grow a variety of plants in one area, such as rice, mango, and citrus, using a method called surjan. This method involves arranging the land into beds with some parts kept wet and others dry, allowing for diverse plant cultivation in the same area (Susilawati et al. 2014).

For generations, peatlands have been vital for the livelihoods of millions, offering multiple ecological functions such as water retention, support for unique biodiversity, and the production of agricultural and forest commodities. These ecosystems are characterized by acidic pH levels, poor nutrients, and frequent inundation. To facilitate agriculture, specific water management practices have been developed to overcome the challenges of cultivating crops on peatland. The main agricultural outputs from peatlands include food crops such as rice, corn, and soybeans; fruit crops like pineapple, banana, melon, mango, rambutan, durian, jengkol, petai, coconut, and liberica coffee; and vegetable horticultural crops including tomatoes, pare, cabbage, cucumber, corn, chili, kale, ginger, and spinach (Agus and Subiksa, 2008).

However, improper management, such as the use of open-system water management instead of closed systems, along with unsustainable farming practices, can lead to wildfires, drought, flooding, subsidence, social disruption, emissions, and the exacerbation of climate change, ultimately resulting in peatland degradation. Peat soils are inherently unstable and vulnerable, necessitating careful planning and implementation of agricultural management practices. As a longstanding solution, techniques now recognized as paludiculture and agroforestry, and familiar to local populations, could address these environmental challenges. These practices are particularly pertinent in Indonesia, which has peatland areas extending over 13.43 million hectares (Anda et al. 2021) and possesses the largest area of tropical peatlands globally and ranks fourth worldwide in total peatland area, following Canada, Russia, and the USA (Syaufina, 2018).

This research brief aims to explore paludiculture and agroforestry, examining their potential to scale up sustainable agriculture or restore degraded peatlands, enhancing productivity. It also assesses the viability of integrating coconut cultivation within these systems, providing insights into how local communities can sustainably utilize peatlands for agricultural purposes, thereby ensuring long-term food security and preserving the ecological integrity of peatland ecosystems.

Paludiculture: Sustainability Concept from Temperate Peatlands

The concept of paludiculture, originating in the temperate regions of North America and Europe, particularly Germany and Poland, addresses the extensive drainage of peatlands historically implemented to enhance crop yields. This practice, however, led to significant peat degradation and subsequent yield reductions (Grootjans, 2017; Wichmann et al. 2016). It is now understood that the adverse effects of draining peatlands can be mitigated by restoring and maintaining higher water levels.

Derived from the Latin word *"palus,"* meaning swamp, paludiculture involves the productive use of wet or rewetted peatlands in a manner that preserves the peat.

This innovative approach promotes the sustainable and productive use of peatlands, which includes rewetting the land, planting suitable vegetation, and revitalizing local communities. The primary aim of this approach is to restore peatlands to conditions that closely resemble their natural state by blocking or filling drainage canals and establishing deep wells, effectively applying closed-system water management to restore and productively utilize degraded peatland (Dohong, 2019; Sutikno et al. 2019).

Research on paludiculture has primarily been conducted in northern peatlands, focusing on ecological impacts. This includes the selection of productive species suitable for cultivation on rewetted peatlands, understanding peatland hydrology, and reducing greenhouse gas emissions (Wichtmann and Joosten, 2007; Lupascu and Wijedasa, 2021; Lahtinen et al. 2022). In these regions, peatlands, often formed from bryophytes and graminoids, are commonly used for bioenergy (Hytönen et al. 2018). Given the lower population density and economic pressures in the north, many of these peatlands have been abandoned and are now undergoing restoration. This facilitates easier revegetation with wetland species and allows a focus on the benefits of natural ecosystems within the paludiculture framework.

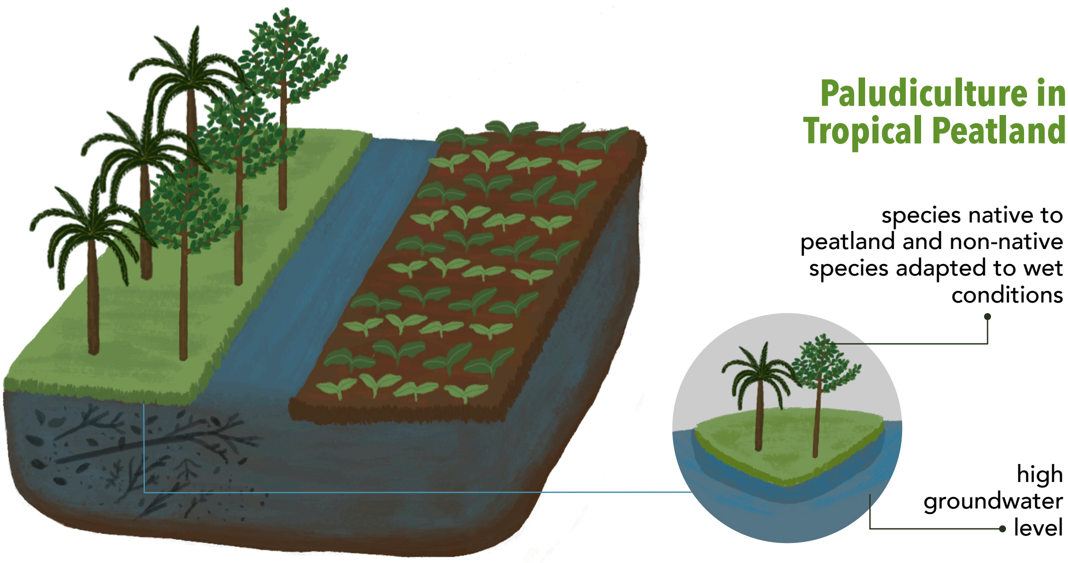

Figure 1. Paludiculture in tropical peatland scheme

Figure 2. Paludiculture in northern peatland. Right: celery cultivation, left: spaghnum farming

In the tropics, the implementation of paludiculture must adapt to and be heavily influenced by socioeconomic considerations, not just the benefits to the ecosystem. Rapid population growth and economic development have led to an increased use of peatlands for farming to satisfy the demand for agricultural products. This has led to an evolving definition of paludiculture, which is now seen as a form of wet agriculture on rewetted peatlands that uses native peat swamp vegetation with the long-term prospects of transforming the ecosystem into carbon neutral or negative sinks, while also providing socioeconomic benefits (Tan et al. 2021).

In paludiculture, selecting appropriate vegetation for cultivation is important. Two types of plants are suitable for peatlands: species native to peat swamps and non-native species adapted to wet conditions. A core principle of paludiculture is the use of these two plant types on wet or rewetted peatlands, managed with a controlled, closed water system. This practice aligns with peatland restoration goals to produce biomass that supports peat formation and offers economic benefits (Schafer, 2012).

A common criterion for paludi-crops is that the vegetation can either be cultivated on wet peatlands or harvested from spontaneous (successional) peatland vegetation, produce utilizable biomass in sufficient quantity and quality, ideally contribute to peat formation or at least to peat conservation, and tolerate waterlogged conditions (Abel & Kallweit, 2022; Tan et al. 2021).

Species such as sago (*Metroxylon sagu*), jelutung (*Dyera polyphylla*), ramin (*Gonystylus bancanus*), balangeran (*Shorea balangeran*), gemor (*Alseodaphne* spp. and *Nothaphoebe* spp.), gelam (*Melaleuca cajuputi*), and *Shorea stenoptera* are native to peat and considered suitable for paludiculture since they can adapt to acidic soils and withstand inundation (Budiman et al. 2020). However, the cultivation of these primarily woody paludiculture species, although economically beneficial, requires a longer time to harvest. Consequently, local communities cannot immediately benefit from these crops. Since socioeconomic benefits are essential for the successful implementation of paludiculture in tropical peatlands, this delay can significantly disrupt the local economy if paludiculture focuses solely on woody plants. Therefore, it is crucial to find solutions to maintain the sustainability of paludiculture implementation in Indonesia.

Agroforestry in Tropical Peatland

Traditional farming, which often focused on monoculture—a system that cultivates a single crop type over a large area—has evolved into a more advantageous and multifaceted system known as agroforestry. Agroforestry integrates trees and crops, enhancing climate resilience and the sustainability of farming systems. Unlike conventional agriculture, agroforestry leverages synergies with natural and social resources across both time and space, aiming to produce food in a sustainable manner (FAO and ICRAF 2019).

Agroforestry is defined as an optimal land use strategy that combines forestry plants (trees) with agricultural crops (seasonal) in a sustainable way, either concurrently or sequentially, within or outside forest areas. This approach seeks to maximize productivity and sustainability without compromising land conservation and the cultivation practices of local communities (Maftu'ah et al. 2021). This evolved definition marks a transformation from monoculture practices to a more diversified agricultural approach that mimics co-cultivation in forest areas, improving productivity and sustainability. Agroforestry is particularly promising for paludiculture because it can be implemented in diverse land conditions, including both wet and dry areas. It offers additional value to communities' post-harvest and serves as a sustainable option for managing peatlands (Maftu'ah et al. 2021).

Agroforestry-paludiculture not only provides economic and environmental benefits but also supports the restoration and rehabilitation of degraded peatlands by integrating economically valuable trees and crops. This mixed cropping approach reduces reliance on single-crop yields, diversifies markets, spreads income, creates more biodiverse systems, and enhances natural pest control (van der Meer et al. 2021). Moreover, the combination of short- and long-rotation biological production systems aims to enhance people's welfare (Lahjie, 2001) while sustaining both short- and long-term economic benefits.

Figure 3. Multi-species and multi-strata agroforests on peatland in Jambi, Indonesia

History and Development of Coconut Agriculture in the Peatlands of Sumatra

The cultivation of coconut in the peatlands of Sumatra has a rich history and development, which can be traced back to the 19th century. The international demand for copra coconut, a key ingredient in soap and margarine production, began to rise significantly around the 1880s (Heersink 1994). During the period from 1909 to 1937, approximately one-third of the global export demand for copra was met by the eastern region of the Dutch East Indies, particularly from Sulawesi Island and the Maluku Islands (Akmal et al. 2021). This dominance, however, was short-lived due to the global economic depression and a decline in copra production caused by disease in Eastern Indonesia. As a result, the global supply of copra shifted towards the East Coast of Sumatra.

The transition of the global coconut supply to the East Coast of Sumatra was facilitated by the emergence of Singapore as a major trading hub in Asia. Commodities from Sumatra, including coconuts, were transited and shipped from Kuala Tungkal, a trading hub in the Kingdom of Indragiri Hilir developed by the Dutch. To meet the growing market demands, Bugis coconut farmers from Sulawesi Island migrated to Sumatra, bringing with them their expertise in coconut cultivation. Concurrently, the Banjar tribe from South Kalimantan also migrated to the East Coast of Sumatra due to conflicts in the Banjar Kingdom.

The East Coast of Sumatra exhibits distinct characteristics compared to Sulawesi Island, primarily due to its peatlands and tidal swamp lands. Fortunately, the Banjar tribe possessed experience in managing swamp lands. The agricultural system in Kalimantan evolved, particularly in the utilization of suboptimal wetlands for productive agriculture. The Banjar tribe in South Kalimantan became experts in managing rice fields and pioneers in developing tidal wetlands for productive rice cultivation. They employed canals (ditches) for water drainage in agricultural lands. Consequently, the development of coconut farming on the East Coast of Sumatra merged the agronomic knowledge and trade experience of the Bugis tribe with the land management skills of the Banjar tribe.

The large-scale development of canals was initiated by Tuan Guru Syekh Abdurrahman Shiddiq in the early 1900s in the coconut smallholder plantation. The peak of copra coconut production on the East Coast of Sumatra occurred during the 1980s and 1990s, when production in the Indragiri Hilir Regency surged and became competitive enough to meet export markets, rivaling copra production from Eastern Indonesia.

Figure 4. Coconut processing (dehusking) by local people in Indragiri Hilir

Currently, 10.6% of Indonesia's coconut production originates from the Indragiri Hilir Regency (BPS Kab. Indragiri Hilir 2021). The coconut commodity on tropical peatlands in the Indragiri Hilir Regency has been a significant economic pillar from the past to the present and is expected to remain so in the future.

Implementing Coconut as Agroforestry-Paludiculture in Tropical Peatlands

The concept of paludiculture has undergone a significant transformation in its scope and application. Initially, it was limited to the utilization of waterlogged or rewetted peatlands for agricultural purposes, primarily aimed at peat restoration. However, recent interpretations have broadened its definition to encompass both ecological and economic advantages for local communities residing in peatland regions. Tan et al. (2021) proposes that biomass production on peatlands can be classified as paludiculture if it maintains groundwater levels near the peat surface and utilizes vegetation that is capable of thriving in waterlogged environments and yields socioeconomic benefits. The essential elements of paludiculture therefore encompass the vegetation's tolerance to waterlogged conditions and its capacity to generate socioeconomic benefits.

The cultivation of coconuts as an agroforestry-paludiculture system in tropical peatlands represents a significant adaptation of traditional agricultural practices to the unique challenges posed by these environments. Coconuts are well-suited to waterlogged conditions and have been cultivated on peatlands for centuries, particularly in the Indragiri Hilir region. The success of coconut cultivation in these areas is largely dependent on the maintenance of appropriate water levels in the soil. Coconut trees require substantial amounts of water to grow and remain productive. However, they are susceptible to axiphication, a condition caused by excessive waterlogging. To prevent this, farmers have developed a management system that involves digging small ditches, known locally as "parit," to regulate the water level. The optimal soil wetness for coconut growth is achieved when the water table is maintained at an average depth of 40-60 cm below the surface.

Coconut trees can withstand regular inundation, such as during high tides or heavy monsoon rains. In smallholder plantations, farmers typically dig a parit every 5 to 6 coconut trees, or approximately every 40-50 meters. These parit are equipped with traditional water gates that control water flow, especially during the harvesting period when transporting coconuts becomes necessary.

In contrast, the industrial coconut plantation in Indonesia employs a closed-system water management practice known as the "Water Management Trinity." This approach utilizes canals for water regulation, reservoir functions, agricultural support, and fire mitigation (Fawzi et al. 2021). The Water Management Trinity is particularly effective in more inland locations where smallholder plantations are not feasible due to their proximity to coastal or river areas. The primary goal of both parit and the Water Management Trinity is to regulate water levels within the coconut plantation, ensuring that the water remains near the surface and supports coconut productivity while preserving peat soil wetness. This strategy aligns with the broader definition of paludiculture, which emphasizes the cultivation of plants on peatlands that are tolerant to waterlogged conditions and provide socioeconomic benefits.

Despite the significant role that coconut production has played in the local economy and culture of Indragiri Hilir, the market price of coconuts can be volatile (Syahza et al. 2019). Furthermore, coconut plantations require a substantial period of maturation before yielding returns, which can strain the immediate financial needs of local families. To enhance local livelihoods in terms of both ecological and socioeconomic benefits, traditional or monoculture coconut plantations in peatland areas could be transformed into agroforestry-paludiculture systems.

In Indragiri Hilir, many farmers have adopted agroforestry and intercropping systems within their coconut plantations, integrating diverse plant species alongside their coconut trees. This approach aims to maximize land productivity and enhance income stability by utilizing the wide spacing between coconut trees to cultivate additional crops. Within the planting space of 8 to 9 meters between each coconut tree, there is sufficient sunlight for additional crops to grow.

Common intercrops found in Indragiri Hilir include areca nut, banana, cassava, pineapple, and liberica coffee. Farmers plant these crops for two main reasons: to increase their income by selling the additional produce in local markets, driven by market demand, and to make efficient use of the ample space between coconut trees. Furthermore, a study a study by Hartawan et al. (2023) showed that intercropping liberica coffee with areca nut and coconut resulted in an 8% increase in productivity compared to monoculture liberica coffee, demonstrating that such integrated systems can significantly enhance overall farm productivity.

The implementation of an intercropping system within a coconut agroforestry framework offers a dual advantage for farmers. This approach not only provides a consistent income through the regular harvests of intercrops but also enhances the sustainability and resilience of the farming system. By diversifying the plant species within the agroforestry setup, farmers can improve soil health, mitigate pest and disease risks, and increase biodiversity, all of which contribute to a more robust and environmentally friendly agricultural practice.

The economic benefits of intercropping in coconut agroforestry are significant. Studies have shown that the combination of high-value crops in these systems can substantially increase farmers' incomes (Wanderi et al. 2019; Notaro et al. 2020). Jaya et al. (2024) reported that coconut agroforestry intercropped with pineapple, celery, spinach, and kangkong had a Benefit-Cost Ratio (BCR) of 10.32, the highest among the studied systems. This high profitability is partly due to the minimal fertilizer requirements and low maintenance needs of pineapples, which are well-suited for growth in peatland conditions.

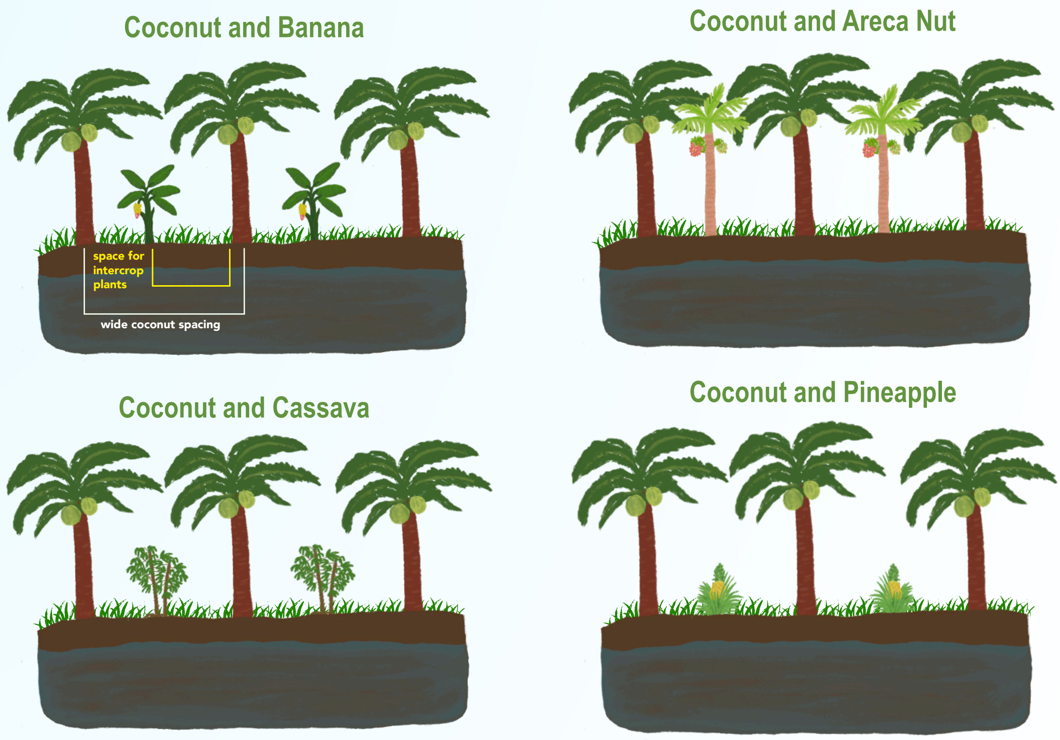

Figure 5. Illustration of coconut agroforestry with banana, areca nut, cassava, and pineapple, commonly found in Indragiri Hilir, Riau. Coconut trees have wide spacing of 8-9 meters apart, making it easier to grow other commodities in between.

Moreover, the adoption of multi-layered coconut agroforestry has been found to yield a higher BCR compared to monoculture systems (Bari and Rahim, 2012). This indicates that the strategic combination of different crop layers in an agroforestry setup can optimize resource use efficiency and economic returns.

In summary, the integration of intercropping in coconut agroforestry not only supports the daily needs of farming families but also contributes to the local economy and food security. The integration of these crops into coconut plantations not only diversifies the local economy but also contributes to the sustainable management of peatlands by promoting the cultivation of plants that are tolerant to waterlogged conditions and provide socioeconomic benefits.

Discussion: Future Prospects

The implementation of agroforestry-paludiculture systems in coconut plantations in Indragiri Hilir could significantly enhance food security by diversifying crops and restoring peatland areas. This approach addresses the four pillars of food security—availability, access, utilization, and stability—which are currently challenged by various factors in the region. In terms of availability, the monoculture of coconut plantations limits the variety and quantity of food produced. Agroforestry, on the other hand, has the potential to increase both food variety and production (Mbow et al. 2014). This system not only enhances food security but also promotes sustainable farming practices that are cost-effective and beneficial for local communities. The findings show that coconut farmers in the region also plant food crops such as chili peppers, spinach, or even rice for self-consumption under the canopy of the coconut trees. This practice demonstrates the integration of food crops into the coconut plantation, enhancing food security and potentially contributing to the sustainability of the farming system.

At the same time, regarding access, poor infrastructure in some parts of Indragiri Hilir complicates the availability of diverse and nutritious food for local communities. Agroforestry can mitigate this issue by providing a wider range of food options, improving access to food for these communities. Additionally, the stability of food supply and agricultural productivity is threatened by climate change and environmental factors. Agroforestry-paludiculture systems can enhance the resilience of agricultural systems by promoting biodiversity and improving soil health, thereby contributing to the stability of food production.

Figure 6. Coconut agroforestry in Indragiri Hilir which increases biodiversity and cover crops, with intercropping of coconut and areca nut, as well as coconut and banana.

Peatland conditions pose additional challenges for local farmers, as they are waterlogged, acidic, and nutrient-poor, making traditional farming methods less effective. Agroforestry-paludiculture systems are specifically designed to thrive in these conditions, offering a viable solution to enhance food security in peatland areas. However, local farmers often lack the knowledge and resources needed to diversify their crops. Smith et al. (2020) found that a lack of resources and knowledge hinders farmers' ability to diversify and improve their farming practices. Therefore, the successful implementation of agroforestry-paludiculture systems in Indragiri Hilir requires not only the introduction of appropriate farming practices but also the provision of training and resources to support local farmers in adopting these practices.

The implementation of agroforestry-paludiculture systems in peatlands can introduce a novel approach to effectively utilize these areas and restore their ecosystems. This system involves the planting of a mix of crops that are suitable for wet conditions, such as certain vegetables, fruits, and trees like coffee and areca nuts. This approach involves maintaining soil moisture by regulating water levels near the surface in the coconut paludiculture-agroforestry system, thereby preventing land fires during the dry season and reducing greenhouse gas emissions. This method promotes long-term sustainable agriculture and conserves the peatland ecosystem. In addition, this approach not only provides a viable option to improve farmers' welfare and maintain household food security (Surahman et al. 2017) but also generates substantial income. Jaya et al. (2024) revealed that intercropping farmers derive approximately 77% of their annual earnings from intercrop farming, demonstrating the economic viability of this system.

In conclusion, the implementation of this approach requires addressing social and environmental challenges. Investing in farmer counseling and training programs can help overcome the social challenges faced by coconut farmers, particularly in Indragiri Hilir. These programs should educate farmers about the benefits and methods of growing different crops alongside coconut trees. Financial support or subsidies for purchasing seeds and necessary equipment can also be provided to equip farmers with the means to explore these new methods. By addressing the unique challenges of peatland conditions and the economic difficulties faced by local communities, integrating paludiculture with agroforestry systems offers a holistic and sustainable solution to improve food security and sustainable peatland utilization.

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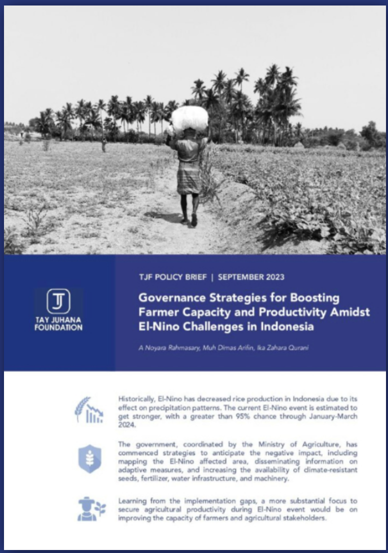
TJF POLICY BRIEF | SEPTEMBER 2023

Governance Strategies for Boosting Farmer Capacity and Productivity Amidst El-Nino Challenges in Indonesia

A Noyara Rahmasary, Muh Dimas Arifin, Ika Zahara Qurani

TAY JUHANA FOUNDATION

Historically, El-Nino has decreased rice production in Indonesia due to its effect on precipitation patterns. The current El-Nino event is estimated to get stronger, with a greater than 95% chance through January-March 2024.

The government, coordinated by the Ministry of Agriculture, has commenced strategies to anticipate the negative impact, including mapping the El-Nino affected area, disseminating information on adaptive measures, and increasing the availability of climate-resistant seeds, fertilizer, water infrastructure, and machinery.

Learning from the implementation gaps, a more substantial focus to secure agricultural productivity during El-Nino event would be on improving the capacity of farmers and agricultural stakeholders.

Policy Brief: Governance Strategies for Boosting Farmer Capacity and Productivity Amidst El-Nino Challenges in Indonesia

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ABOUT TJF

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.

CONTACT US

For further discussion on the TJF Brief and any publications, or to submit an article, please contact us.

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