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Land Management of Tidal Swamp Type B with Surjan System as Climate Change Anticipation

Ani Susislawati, Lutfi Izhar, Achmad Adi Surya Sustama

Indonesian Swampland Instrument Standard Testing Institute (ISWASTI), Banjarbaru, South Kalimantan 70712

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Correspondence:
Ani Susilawati
Indonesian Swampland Instrument Standard Testing Institute, South Kalimantan, 70712
Email: ani.nbl@gmail.com

ABSTRACT

Agriculture is one of the most vulnerable sectors to climate change, which can significantly impact national food security. In addition to climate change, agricultural development faces challenges, including the conversion of agricultural land for non-agricultural purposes. As a result, agricultural extensification has expanded into marginal lands, such as tidal swamplands. This paper presents a literature review on the characteristics of tidal swamplands, the principles of the surjan system, and its relevance in addressing climate change, particularly in the context of food security and ecosystem sustainability. Various literature sources were analyzed to assess the advantages, challenges, and sustainable management strategies of tidal swamplands. The review highlights the importance of effective land management to create suitable soil conditions for optimal plant growth and increased productivity. The surjan system, a land management approach practiced by tidal swampland farmers, demonstrates high adaptability in mitigating the impacts of climate change. This system integrates cultural, ecological, and economic perspectives by combining local knowledge with technological advancements. Key components of the surjan system include a one-way water management system with flap-gates and stoplogs, as well as the use of climate-adaptive crop varieties on tidal swamplands.

KEYWORDS

adaptive cropping, food security, resilience, sustainable agriculture, water management

1. INTRODUCTION

Swamplands in Indonesia play a crucial role in agricultural development, particularly amid rapid population growth, industrial expansion, and the ongoing conversion of fertile land for non-agricultural purposes (Sulaiman et al., 2019). Population growth and socio-economic progress are increasing the demand for food and better nutrition, highlighting the urgent need to enhance agricultural production. Consequently, agricultural intensification, extensification, and diversification have become both necessary and unavoidable strategies. Given the limited availability of fertile land and the rising demand for agricultural products, utilizing suboptimal lands, including swamplands, has become a logical alternative (Mulyani et al., 2023).

To address this, the government has promoted agricultural development in marginal lands such as swamplands, as these land resources remain underutilized. However, their contribution to agricultural production remains low, primarily due to suboptimal land management. Factors such as poor soil chemistry, environmental constraints that hinder plant growth, cropping patterns still dominated by a single planting cycle per year (IP 100), and limited adoption of modern agricultural technologies continue to characterize the conditions of tidal swamplands (Murjani, 2024).

One of the provinces with a considerable area of swamp land is South Kalimantan. South Kalimantan has an area of approximately 4,969,824 ha of swamp land, consisting of tidal swamp land and lebak. The contribution of swamp land to agricultural production is still

(a) (b)

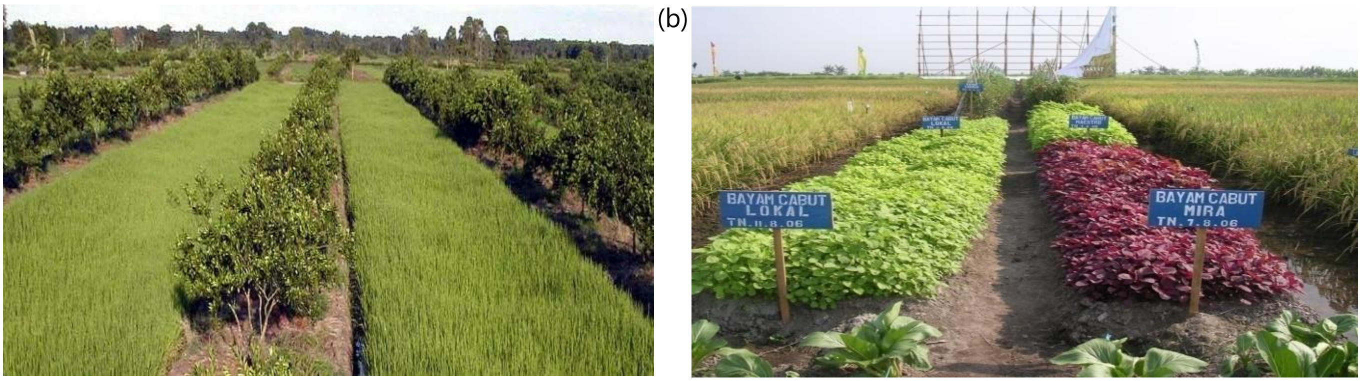

Figure 1. Performance surjan system on the swampland with (a) rice and orange pattern, (b) rice and vegetables pattern.

relatively low. In 2020, rice production in South Kalimantan was only 1.1 million tons of milled dry grain (Statistic Indonesia, 2021). To increase food production, the government has launched a swamp land optimization program in 2024, therefore South Kalimantan aims to optimize 41,829 ha of swamp land spread across 8 districts.

The chemical properties of swamp soils often create unfavorable conditions for plant growth. These challenges include low soil pH, high concentrations of aluminum (Al), iron (Fe), manganese (Mn), and sulfate (SO_4), elevated soil salinity, and deficiencies in essential nutrients such as phosphorus (P), copper (Cu), zinc (Zn), and boron (B). In newly cleared swamp areas, soil acidity is particularly high, with pH levels often below 4 and Fe^{2+} concentrations reaching 300–400 ppm (Clough et al., 2000).

A major issue in acid sulfate soils is the oxidation of pyrite (FeS_2). Under natural conditions, the pyrite layer remains in deeper, anaerobic soil layers. However, land development activities such as reclamation and tillage can disturb this layer, bringing pyrite to the surface, where it undergoes oxidation (Armanto, 2014). Pyrite is highly reactive in aerobic conditions, leading to a drastic drop in soil pH to 2–3, which severely inhibits plant growth (Van Mensvoort and Dent, 2020).

The oxidation of pyrite occurs in multiple stages involving both physicochemical and microbiological processes. Initially, oxidation by oxygen occurs slowly, producing Fe^{2+}, SO_4^{2-}, and H^+. This process is catalyzed by autotrophic bacteria at near-neutral pH, with a half-life ranging from 20 to 1,000 minutes (Demoisson et al., 2008). Additionally, Fe^{3+} acts as a more aggressive oxidizer, facilitating even faster oxidation than Fe^{2+} itself. Oxygen can enter the soil through cracks, former plant root channels, and water flow, which introduces both oxygen and Fe^{3+}. Excessive reclamation or drainage efforts intended to reduce waterlogging during the rainy season can lead to severe drying during the dry season, rendering agricultural land barren (Zade et al., 2021).

Beyond soil-related challenges, environmental stressors associated with climate change, such as floods, droughts, and seawater intrusion, further complicate land management for farmers. Climate change affects swamp lands in multiple ways, including hydrology, ecology, and socio-economic conditions. The changes in global temperature and rainfall patterns impact water availability in wetlands, increasing the frequency of droughts and extreme flooding (IPCC, 2023). Additionally, rising evaporation rates due to climate change can disrupt wetland water supplies (Mitsch and Gosselink, 2015). Moreover, several studies indicate that swamp drainage exacerbates greenhouse gas emissions, particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Yang et al., 2018). Climate change also affects livelihoods in swamp regions, as seen in the Mekong Delta and along Sumatra's east coast (Brown et al., 2018; Dong et al., 2024). Therefore, effective land management strategies are essential to mitigate soil degradation and environmental stress caused by climate change.

Tidal swamp lands can be classified into four types based on the extent of tidal water influence: Type A, B, C, and D. Among these, Type B offers the highest potential for agriculture due to its moderate tidal intensity, making it more suitable for cultivation. One traditional yet effective approach to swamp land management is the surjan system, which has been practiced by farmers for generations. This system remains widely used because of its economic benefits and adaptability. Farmers have further enhanced the surjan system by incorporating technological advancements. The surjan system is particularly applicable to acid sulfate soils and shallow peatlands of types B and C.

By implementing this method, farmers can diversify their crops, growing not only rice but also fruits (e.g., oranges and pineapples), secondary crops, vegetables,

Table 2. Management and land utilization pattern based on typology and water overflow on tidal swampland (Source: Widjaja-Adhi, 1995).

Typology land		Utilization land on type water overflow			
Code	**Typology**	**A**	**B**	**C**	**D**
Potential Sulphate Acid-1	Alluvial sulfide - shallow	Ricefield	Ricefield	Ricefield	-
Potential Sulphate Acid-2	Alluvial sulfide - deep	Ricefield	Ricefield (surjan)	Ricefield (surjan)	Ricefield (moor, farm)
Potential Sulphate Acid-3/A	Alluvial sulfide - very deep	-	Ricefield (surjan)	Ricefield (moor)	Moor (garden)
Actual Sulphate Acid-1	Alluvial sulfate 1	-	Ricefield (surjan)	Ricefield (surjan)	Ricefield (moor, farm)
Actual Sulphate Acid-2	Alluvial sulfate 2	-	Ricefield (surjan)	Ricefield (surjan)	Ricefield (moor, farm)
Actual Sulphate Acid-3	Alluvial sulfate 3	-	-	Ricefield (farm)	Moor (farm)
	Alluvial sulfide shallow	-	Ricefield	Ricefield (moor)	Moor (farm)

and other perennial plants. These can be cultivated as monocultures or through intercropping. This paper explores various aspects of the surjan system as a tidal swamp land management strategy to address climate change challenges. Additionally, it examines how this traditional system has been enriched with modern research-based technologies to enhance its effectiveness and sustainability.

2. SURJAN SYSTEM IN SWAMP LAND

Swamps are wetland ecosystems characterized by permanently or seasonally water-saturated soil. These ecosystems play a crucial role in maintaining global environmental balance, serving as carbon storage, biodiversity habitats, and natural water filters (Joosten et al., 2012; Mitsch et al., 2015; Mitsch and Gosselink, 2015; Yan et al., 2023). Swamps are found across various climates and geographical conditions, from tropical regions to temperate and cold climates. Managing tidal swamp land requires an integrated approach that considers environmental, social, and economic factors. With the application of appropriate technologies and effective management strategies, these lands can be transformed into valuable resources for food security and sustainable development.

The term surjan originates from Javanese, meaning lurik or lines. When viewed from above, surjan fields resemble a series of alternating linear patterns formed by raised and sunken beds. The elevated portion (tegalan) is typically planted with dryland crops such as secondary crops, vegetables, and horticultural plants, while the lower portion (tabukan) is utilized for rice cultivation (Suriadikarta and Setyorini, 2006). This land management system not only optimizes land use in swamp areas but also enhances agricultural resilience against water level fluctuations.

Although the surjan system is rooted in Indonesian local wisdom, similar concepts have been adopted in other countries with modifications suited to local environmental conditions. Several examples include:

- Bangladesh: Farmers employ floating bed cultivation, a technique similar to the surjan system. Organic materials such as straw and water hyacinth are used to construct floating beds, enabling the cultivation of vegetables and rice in flood-prone swampy areas (Karmaker et al., 2023).
- India: In regions like West Bengal and Odisha, raised bed farming is practiced to mitigate waterlogging caused by heavy rainfall and seasonal flooding. Trenches are dug between planting areas to improve drainage and maintain soil aeration (Singh et al., 2010).
- Mekong Delta, Vietnam: Farmers implement high bed systems to cultivate rice and horticultural crops, mitigating the effects of tidal water fluctuations and improving soil conditions (Nguyen et al., 2024).
- Australia: In areas with high soil salinity and waterlogging risks, raised bed farming is utilized to enhance water movement, reducing excess moist-ure stress on crops (White and Sands, 2017).

The widespread adoption of similar techniques worldwide underscores the effectiveness of raised-bed farming systems like surjan in managing wetland agriculture. By integrating scientific advancements and traditional knowledge, such systems can contribute to sustainable land use and climate resilience in swamp.

The Surjan system requires careful consideration of the relationship between land typology, overflow type, and utilization patterns, particularly concerning the presence of pyrite layers. Recommendations for land management in reclamation and tidal land development are summarized in Table 1, which outlines the appropriate land-use patterns based on typology and overflow classification. In potential acid sulfate soils with overflow type A, the land should be managed as flooded rice fields to maintain anaerobic conditions, stabilizing pyrite and preventing oxidation, which ensures optimal rice growth. The Surjan system is best suited for overflow types B and C, whereas overflow type D is more appropriate for dryland farming systems.

The economic benefits of the Surjan system are significantly higher than those of conventional rice field systems. This is because the multi-purpose land use and multi-commodity approach enable farmers to diversify their crops, leading to higher and more stable income streams. In terms of food security, this system supports three key principles for increasing food availability. The Surjan system optimizes both space and time in agriculture by integrating a variety of crops and cropping patterns. In contrast, monoculture-based systems, such as rice fields for paddy, raised beds for upland rice, or plantation systems for perennial crops, tend to rely on a single commodity, which exposes farmers to higher risks if that crop fails (Susilawati et al., 2017).

The Surjan system is particularly suited for swampland conditions, where hydrological constraints and inadequate water management often lead to high crop failure risk (Susilawati and Nursyamsi, 2014). By adopting this system, farmers can mitigate risks, even if rice harvests fail, they still have secondary crops or vegetables as an alternative income source. The Surjan system has been successfully implemented in Malaysia, Thailand, and Vietnam for agricultural use on swamplands (Noor, 2004). A case study in South Kalimantan demonstrated its effectiveness in increasing crop yields (Kasno, 2015). Similarly, successful implementation in South Sumatra where local farmers improved rice and horticultural production using this system (Islami and Rahmat, 2020).

Farmers commonly adopt polyculture cropping patterns within the Surjan system, cultivating multiple crops in both tabukan (sunken beds) and guludan (raised beds). Tabukan (sunken bed) serves as a water storage area and is typically 15 m wide. It is mainly used for water-dependent crops like rice and can also support aquaculture, such as rice-fish farming. Guludan (raised bed) is formed by excavating soil from the surrounding area. It is 3–5 m wide and 0.5–0.6 m high, and is used for growing secondary crops, vegetables, or horticultural plants.

Polyculture farming offers several advantages, including more efficient and sustainable resource use and higher resilience to crop failure (Beets, 2019). If one crop, such as rice, fails, farmers can still harvest alternative crops like chilies or vegetables. Polyculture also contributes to natural pest control. Intercropping systems also help reduce insect pests, diseases, and weeds by promoting the presence of natural predators (Afrin et al., 2017). Additionally, ecosystems with high biodiversity have more complex food chains, which contribute to ecological balance and greater resilience to disturbances (Oliver et al., 2015).

Comparative studies on rice fields within the Surjan system versus conventional rice fields indicate that Surjan-based rice fields are more resistant to pest outbreaks, particularly soil bedbugs (Tandjung et al., 2012). The diverse habitat structure, comprising both wet (aquatic) and dry (terrestrial) environments, creates more interactions among biological components, leading to greater ecological stability and pest resistance.

3. CLIMATE CHANGE THREAT TO AGRICULTURAL PRODUCTION SYSTEMS

Climate change is an unavoidable global phenomenon that affects various aspects of life, particularly agriculture (Yuan et al., 2024). In Indonesia, agriculture plays a crucial role in food production and employment. Climate change leads to several environmental changes, including (a) rising air temperatures, (b) increasing sea levels, (c) shifting rainfall patterns, and (d) more frequent extreme weather events (Portner et al., 2022). Numerous studies indicate that climate change contributes to declining agricultural productivity due to higher temperatures, floods, droughts, increased pest and disease infestations, and reduced crop quality (Jägermeyr et al., 2021; Karki et al., 2020; Lesk et al., 2021; Yang et al., 2023).

A strong correlation exists between climate change and agricultural production (Yuan et al., 2024). Its impacts are multidimensional, affecting natural resources, agricultural infrastructure, production systems, food security, farmer welfare, and society. Among extreme climate events, drought ranks as the leading cause of crop failure, resulting in decreased agricultural output and lower farmer incomes (Orimoloye, 2022). In climate change indirectly affects productivity by intensifying pest and disease outbreaks (Manik et al., 2020). For instance, during the rainy season, fungal diseases such as rice blast, rice sheath blight, and anthracnose in chili plants become more prevalent (Asibi et al., 2019; Manathunga et al., 2024). Conversely, in the dry season, pests like rice stem borers, migratory locusts, and thrips pose significant threats (Subedi et al., 2023).

High-temperature stress is a major limiting factor

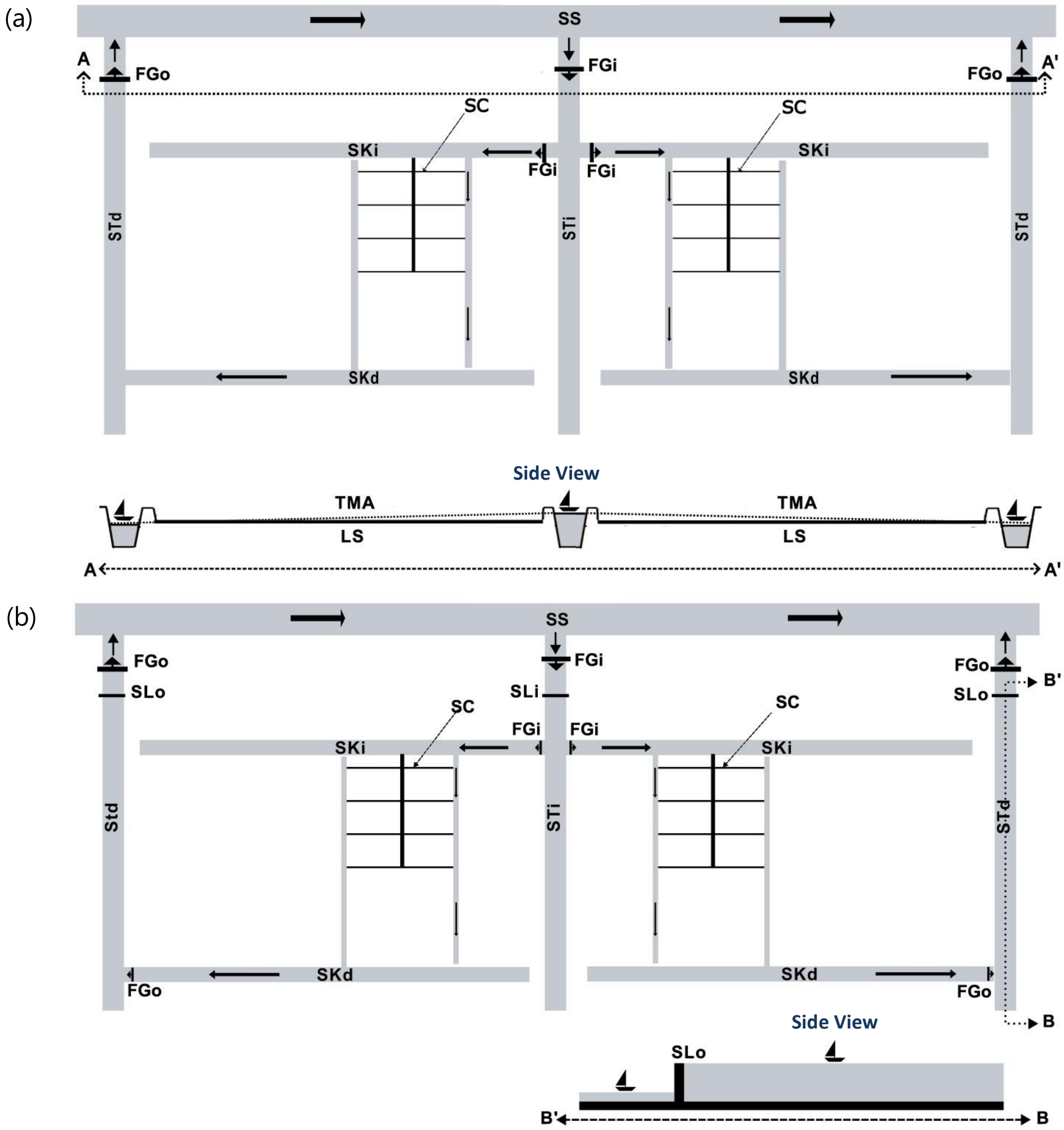

Figure 2. Top and side view illustration of (a) a one-way flow system and (b) a combined one-way flow system with a conservation Tabat system. SS: secondary channel, STi: irrigation tertiary channel, STd: tertiary drainage channel, SKi: irrigation quaternary channel, SKd: drainage quaternary channel, SC: worm channel, FGi: flapgate inlet, FGo: flapgate outlet, LS: rice field, TMA: paddy field level. (Source: National Standardization Agency, 2024).

for plant growth and production, even in tropical regions. Excessive radiation and elevated temperatures can lead to pre- and post-harvest damage, including leaf and twig burns, early leaf senescence, inhibited root growth, fruit discoloration, and yield reduction. Rising temperatures accelerate transpiration, decreasing crop productivity (Sadok et al., 2021). Additionally, higher temperatures increase water demand, hasten fruit and seed maturation, degrade yield quality, and promote pest and disease proliferation. Global warming significantly reduces food crop productivity, particularly in tropic regions (Yuan et al., 2024). In China, yields loss up to 17% for every additional 0.5°C (Wang et al., 2023), similarly in US projections of changes in temperature suggest that maize yields will decline by 39 to 68% by 2050 (Kim and Lee, 2023).

Swamp land is particularly susceptible to climate change, with negative effects outweighing potential benefits. These fragile ecosystems face challenges such as unpredictable water fluctuations, which result in droughts and floods. Acid sulfate swamp lands, El Niño induced pyrite oxidation can lead to sulfate and iron toxicity when flooded, while in dry conditions increase aluminum toxicity, salinity, and pest infestations (Nugroho et al., 2021). Peatlands experience severe drought during El Niño events, making them highly prone to fires and increasing carbon emissions (Sulaiman et al., 2023). Conversely, during La Niña, extensive flooding reduces the area available for crop cultivation. In tidal swamp lands, shifts in cropping pattern

Table 2. The production of paddy on three type water management on tidal swampland – acid sulphate land, Danda Jaya, South Kalimantan (Source: Noorginayuwati, 1991).

Management / Variety	Average yield (kg/ha)
Traditional local rice	1,817
Two ways	
- Superior rice	3,261
- Local rice	2,506
One way	
- Superior rice	4,188

occur, and under La Niña conditions, plant able areas decrease (Khairullah et al., 2021).

The impacts of climate change are already evident in several regions across Indonesia. Prolonged dry seasons, shorter but more intense rainy seasons (Ferijal et al., 2021), and shifts in seasonal patterns make it increasingly difficult for farmers to determine optimal planting times, leading to frequent crop failures (Ansari et al., 2023). A decline in agricultural productivity threatens national food production and disrupts overall food security. Under the RCP 8.5 scenario, temperature increases could lead to a rice yield reduction of up to 11.77% by the 2050s (Ansari et al., 2023). Additionally, for every 1°C increase in annual average temperature, rice yields are expected to decrease by 3.2% (Zhao et al., 2017). El Niño during the paddy planting period significantly reduces paddy production (Mulyaqin, 2020). In the long run, a 1-point increase in the Multivariate ENSO Index (MEI) can reduce paddy production by 50 tones (Ismail and Chan, 2020).

Geographically, tidal swamp lands are directly influenced by rising sea levels, increased temperatures, changing rainfall patterns, and more frequent extreme weather events (Kirwan and Megonigal, 2013). These changes significantly impact tidal ecosystems and the communities that depend on them. Farmers in these regions have long adapted to climate variability through various mitigation and adaptation strategies. One such strategy is the surjan system, which integrates multiple cropping techniques to enhance resilience against climate change.

4. ANTICIPATING CLIMATE CHANGE TO STRENGTHEN FOOD SECURITY

Climate anomaly events such as changes in rainfall intensity and patterns, rising air temperatures, droughts, floods, and increased intensity of pest and disease attacks are symptoms of climate change that can impact the productivity of agricultural crops, particularly food crops (Ansari et al., 2023; Subedi et al., 2023; Wang et al., 2023). Anticipation of the impacts of climate change can be achieved through mitigation and adaptation.

Mitigation is an effort to reduce the rate of climate change through adjustments and improvements to agricultural practices and technologies, while adaptation is an effort to reduce the impacts of climate change on agricultural systems and production through adjustments and improvements to agricultural infrastructure (facilities and infrastructure) and adjustments through adaptive agricultural technology (Sekaranom et al., 2021; Twidyawati et al., 2021). Mitigation and adaptation efforts that can be made include optimal and sustainable management of land and water resources, crop management that is adjusted to local climate conditions, the application of effective and efficient agricultural production facilities, and the application of appropriate and adaptive agricultural technology (Iglesias and Garrote, 2015; Malhi et al., 2021).

Initially, the surjan system was intended for food diversification which is a very important aspect in food security. In addition, this system is also useful for efforts to increase farmer income and reduce business risks. Furthermore, along with the rapid development of agricultural technology, this system has developed and is equipped with various technologies to increase crop production, mitigation, and adaptation to climate change in tidal lands. Some of these technologies are discussed in this paper.

4.1 Water Management

Water management is one of the keys to the success of developing swampland for agriculture. Water management systems that have been tested well in tidal land are the one-way flow system and the dam overflow system (Figures 2). The implementation of this water management system needs to be adjusted to the land typology and type of water overflow and the commodities being cultivated. In type A overflow type (Figure 2a), a one-way water management system can be applied, while in type B overflow (Figure 2b), a one-way and dam overflow water management system can be applied, because high tides in the dry season often do not enter the land plot. In types C and D overflow, a dam overflow system can be applied which is intended to conserve water, because the water source only comes from rainwater. Therefore, the water channels in the water management system in types C and D overflow need to be equipped with dam overflow or stoplog doors to maintain the groundwater level so that it is in accordance with plant needs and allows rainwater to be collected in the channel.

The one-way flow system is designed in such a

Table 3. Types of commodities, varieties of adaptive crops, and yield potential range in tidal swampland (Source: Agustiani et al., 2022; Darsani and Alwi, 2021; Susilawati et al., 2016).

Commodity type	Varieties	Yield (t/ha)
Maize	Arjuna, Kalingga, Wiyasa, Bisma, Bayu, Antasena, C-3 & 5, Semar, Sukmaraga, Padmaraga Bisi 2	4 — 6
Soy bean	Wilis, Rinjani, Lokon, Dempo, Galunggung, Merbabu, Petek, Kerinci, Tampomas, Sibayak, Tanggamus, Slamet, Lawit, Menyapa, Depas 1, Depas 2, Anjosmoro,	1.5 — 2.9
Peanut	Gajah, Pelanduk, Kelinci, Singa, Jerapah, Komodo, Mahesa	1.8 — 3.5
Mung bean	Betet, Walet, Gelatik	1.5
Tomato	Intan, Permata, Berlian, Mirah, AV-22, Ratna	10 — 15
Chilli	Tanjung-1 dan 2, Barito, Bengkulu, Tampar, Keriting, Rawit hijau dan putih, Hot Chilli	4 — 6
Eggplant	Mustang, Kopek ungu, Ungu panjang No. 4000	30 — 40
Cabbage	KK Cross, KY Cross, Grand 33	20 — 25
Snake bean	Pontianak, KP-1, KP-2	15 — 20
Snaps	Horti-1, Horti-2, Prosessor, Farmer Early, Green Leaf	6 — 8
Cucumber	Saturnus, Mars, Pluto	35 — 40
Shallots	Ampenan, Bima,	4.8 — 6.4
Mustard	Asveg-1, Sangihe, Talaud, Tosakan, Putih Jabung, Sawi hijau, Sawi huma	15 — 20
Lettuce	New Grand Rapids	12 — 15
Spinach	Maestro, Giti hijau dan merah, Bangkok, Cimangkok, Kakap hijau	10 — 12
Water Spinach	LP-1, LP-2, Sutera	25 — 30
Watermelon	Sugar Baby, New Dragon	15 — 25
Pepper	Petaling-I, Petaling-II, LDK	3.0
Orange	Siam Banjar	12

way that water is managed to enter and exit through different tertiary channels. For this reason, automatic flap gates are installed at each tertiary channel outlet. The gates on the inlet (irrigation) channels are designed semi-automatically, namely only opening inwards. at high tide and closes itself at low tide. In the drainage channel, a water gate is installed that opens outwards so that it will only release water into the tertiary channel when there is low tide. This system allows water circulation in one direction, both surface water and groundwater. Water that enters through the irrigation channel into the land plot is drained out through the drainage channel. Furthermore, in the quarter channel, a water level control gate (stoplog) is installed which can be opened and closed manually according to needs. The application of a one-way flow water system, in addition to facilitating the washing of toxic elements, also allows the development of various planting patterns as long as it is accompanied by a water management system at the tertiary level that is appropriate for the type of overflow and a micro water management system at the land plot level (Sarwani, 2002).

The application of one-way flow system water management in acid sulfate land has been proven to increase land productivity. Noorginayuwati (1991), reported that the application of one-way flow system water management gave the highest rice yield compared to traditional water management and two-way water management (Table 2). This was reinforced rice yield in acid sulfate land overflow type B Tatas Unit, Central Kalimantan could increase by 60% in the dry season and 120-150% in the rainy season.

The increase in land productivity and rice yields is closely related to the improvement in groundwater quality after the implementation of a one-way flow system, especially the decrease in Fe^{2+}, Al^{3+} and $SO_4{}^{2-}$ content. Water management in the face of climate change is one of the very important factors and must be done immediately. Inundation and drainage greatly affect the physio-physicochemical processes of plants-soil-water such as pH, Eh, and air circulation which play a role in the chemistry reaction process and soil microbes activity related to greenhouse gas emissions (GHG) especially methane and N_2O (Las et al., 2006).

Water management technology in tidal swamp areas is one of the key factors for the success of agricultural activities in such environments. If water regulation cannot be controlled, it not only leads to failure but also causes various environmental damages (Knox et al., 2012). This is because water supply and inundation duration in swamp lands determine rice production (Ansari et al., 2023). Water management is essential to meet crop water needs in both rainy and dry seasons. It plays a crucial role in providing irrigation for adequate plant growth, soil conservation, leaching toxic elements/compounds such as Al, Fe, and H_2S, enriching nutrients from water, and serving as a mitigation effort to reduce greenhouse gas (GHG) emissions. In acid sulfate tidal swamps, flooding and the addition of organic matter for six weeks in rice cultivation can increase soil pH to $\geqslant$ 5.0 (Annisa et al., 2011). There is a significant relationship between crop yield reduction and groundwater levels (Tan et al., 2023).

4.2 Crops Arrangement

Crop production in tidal swampland can be increased by using adaptive varieties. Inpara (Inbrida Padi Rawa) is a variety that is adaptive to swamp land and has been released by Balitbangtan since 2012, namely: Inpara 1, Inpara 2, Inpara 3, Inpara 4, Inpara 5, Inpara 6 and Inpara 7 have high yield potential (4-7 t/ha), adaptive to swamp land (inundation, high acidity, and iron poisoning), and have a shorter maturity (115-135 days) compared to local varieties (210-270 days). Previously, in 2000, 2 varieties of swamp paddy were also released, namely Margasari and Martapura. Both of these varieties have advantages: high yield potential (4.5-5 t/ha), dry rice taste (according to local tastes), short maturity (120-125 days) and adaptive in swamp land (Suprihatno et al., 2010).

The utilization of swampland with increased planting index (IP) will provide a significant contribution to increasing national rice production. Because of its early maturity, the use of superior varieties supported by good water and soil management allows farmers to plant it twice a year. Thus, the use of superior varieties in addition to increasing production per unit area also increases production per unit time. Until now, local rice still dominates rice planting in swampland, especially tidal swampland. Farmers in swampy areas generally cultivate rice only once a year (cropping index/IP 100), with only about 10% of the area implementing two planting cycles per year (Haryono, 2013). One of the factors contributing to the low rice cropping index is farmers' limited ability to adopt technology (Ambali et al., 2021), including the adoption of new superior rice varieties (VUB). The use of long-duration local rice varieties, which can take up to six months to mature, poses a challenge to increasing the cropping index. An alternative to achieving two planting cycles per year (IP 200) is the combination of local varieties with VUB (Thamrin et al., 2017).

The Ministry of Agriculture has released VUB varieties adapted to swampy lands, featuring medium growth durations, which can serve as an alternative to increase the cropping index to two rice plantings per year. These new superior varieties not only have shorter growth durations but also offer higher yield potential, preferred taste characteristics among local farmers, and resistance to biotic and abiotic stresses specific to swamp environments (Koesrini et al., 2017; Rumanti et al., 2016)

Utilization of tidal swampland for horticultural crops can provide added value for farmers. Several types of plants that are widely cultivated in tidal land because they have proven to be adaptive and profitable can be seen in Table 3. The performance of the results and tolerance of plants vary greatly depending on the level of environmental stress and their management. Nutrient management and the use of tolerant varieties in acid sulfate land have been shown to increase the yield of various types of vegetables (Sulaeman et al., 2024). The discovery of varieties that are resistant to salinity, drought, and puddle is hope from all over resident world in face climate change in the future, so that threat hunger and crisis food can resolved.

5. CONCLUSION

Climate change poses a significant challenge to food security, particularly in regions reliant on swamp and tidal lands for agricultural production. Rising temperatures, shifting rainfall patterns, and extreme weather events directly impact crop yields, soil conditions, and water availability, making sustainable agricultural practices essential.

One of the most effective strategies to address these challenges is the implementation of water management systems tailored to specific land typologies. The one-way flow system and dam overflow system have been proven to enhance land productivity, particularly in acid sulfate soils, by improving groundwater quality and reducing toxic element concentrations. Proper water regulation helps mitigate the adverse effects of climate variability, ensuring stable crop production throughout the year.

Additionally, mitigation and adaptation strategies such as the surjan system, integrated cropping techniques, and the use of advanced agricultural technologies, play a crucial role in strengthening farmers' resilience to climate change. The surjan system is one of land management which is usually implemented by swampland farmer and proven capable to anticipate climate change. This system has own perspective culture, ecology, and economy, which combines between local wisdom and the novel innovation technology. Technology set in the surjan system includes: one way flow system - water management which equipped automatic door (flap gates) and dam overflow (stoplog) and use adaptive crops for swampland.

By optimizing land and water resource management, improving infrastructure, and applying climate-adaptive technologies, agricultural productivity in swamp lands can be sustained and even enhanced. To ensure long-term food security, it is essential to continue developing and refining climate resilient agricultural practices. Further research and collaboration among policymakers, scientists, and farmers will be necessary to implement sustainable solutions that address the evolving challenges posed by climate change.

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