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Enhancing Rice Productivity and Ensuring Food Security in Indonesia through the Adoption of Innovative Technologies in Tidal Swamp Rice Farming

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ABSTRACT: The expansion of rice cultivation areas in tidal swamp lands is crucial for Indonesia to increase rice production in order to meet the rising food demand in line with population growth. The purpose of this study is to comprehensively explore and assess innovative technologies that can be developed for rice cultivation in tidal swamp lands. The research was conducted using ScienceDirect (Core Collection) with keywords "Tidal Rice Farming," "Rice Productivity," "Technology," and "Food Security in Indonesia," and Google Scholar with keywords "Rice Production," "Tidal Swamp Rice," and "Indonesia," following the guidelines from PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The research includes peer-reviewed studies published between 2014 and 2024, focusing on the recent technology of rice farming in tidal swamp fields. The research result show Tidal swamp land in Indonesia, covering 8.92 million ha with mineral soil 7.56 million ha and peat soil 1.36 million ha, mainly used for rice farming 2.8 million ha. The current rice productivity ranges between 4-5 million tons of unhulled rice per year. This finding concludes that the adoption of innovative technologies can be applied to increase rice productivity in tidal swamps, which holds great potential for enhancing food security in Indonesia. The study also highlights the importance of additional research to address challenges such as soil salinity, water availability, accessibility, and the adoption of these technologies across different tidal swamp land conditions.

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KEYWORDS: Rice farming, Food Security, Salinity, Coastal line, Technology, Tidal Swamp, flood-prone

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INTRODUCTION

Food security is a fundamental human right and an essential prerequisite for human development. In Indonesia, food security is a significant concern due to the country's large population and diverse geographical conditions. The United Nations has identified food security as a critical issue in Indonesia, with the country ranking 63rd out of 113 countries in the Global Food Security Index.

Land extensification emerges as a potential solution for increasing food security in Indonesia. With limited arable land and growing population pressure, increasing agricultural land area offers opportunities to boost domestic food production and reduce reliance on food imports (BPS, 2020). Furthermore, expanding agricultural land into currently underutilized or degraded areas has the potential to enhance rural livelihoods, alleviate poverty, and stimulate economic development in remote regions (Barbier et al., 2014).

Tidal swamp areas present a promising opportunity for increasing food security in Indonesia. Tidal swamp lands, characterized by fluctuating water levels and saline soils, remain underutilized for agriculture (Widiarta et al., 2020). Expanding agricultural activities in these areas has the potential to increase domestic food production, reduce dependence on imports, and improve livelihoods in rural communities (Pramukanto et al., 2017). However, the suitability of tidal swamp lands for agricultural extensification varies depending on factors such as soil salinity, water availability, and accessibility

MATERIALS AND METHOD

The research focused on peer-reviewed studies that measured recent technology of rice farming in tidal swamp field. Searches were performed of Science Direct (Core collection), and Google Scholar following guidelines from PRISMA (Preferred Reporting Item for Systematic Review, Supplementary Fig. S1). The research included all articles published between 2014 and 2024. Study titles and abstracts were scanned manually during the first selection, excluding studies that needed more information on the recent technology of rice farming in tidal swamp field.

The data resource used in this study refer to databases and indexes that can be accessed on ScienceDirect. Keywords that used in this research on ScienceDirect "Tidal Rice Farming AND Rice Productivity AND Technology AND Food Security in Indonesia". In Google Scholar keywords that used in this research was "Rice Production AND Tidal Swamp Rice AND Indonesia". The diagram in Figure 1 provides a succinct overview of the algorithm's flowchart. The criteria for selection involve scientific publications in the form of research articles, specifically those published between 2014 and 2024. The selection is based on the evaluation of titles and abstracts.

The initial search on ScienceDirect yielded 181 journals. These were subsequently filtered based on publication date between 2014 and 2024, article type (research articles), and open access availability, resulting in a final selection of 11 research articles. The research in Google Scholar resulted in 17.600, and screening for time published between 2014 and 2024, the resulting in 10.600 articles. Following a full-text screening and excluding article reviews, 6 journals that met the specified criteria were identified, containing the relevant information.

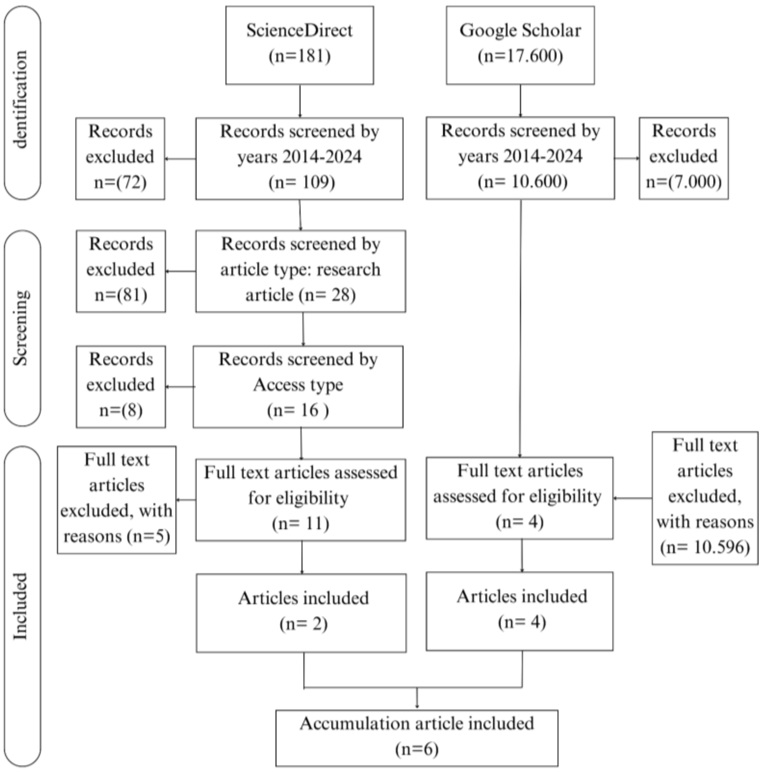

Figure 1. Flow Chart Methods Systematic Literature Review: Assessing the Current State and Future Trends of Land Use Conversion: Implications for Food Security in Indonesia

RESULT AND DISCUSSION

Current Situation of Tidal Swamp Rice Farming in Indonesia

The area of tidal swamp land in Indonesia covers approximately 8.92 million ha, which is divided into mineral soil and peat soil. Mineral soil accounts for 7.56 million ha, while peat soil comprises 1.36 million ha. The largest area of tidal swamp land is located on Sumatra Island, with 3.02 million ha. Kalimantan follows with 2.98 million ha, and Papua has 2.43 million ha. Tidal swamp land in Indonesia is primarily used for rice farming, covering an area of 2.8 million ha. Tidal swamp land contribute to national rice stock around 4-5 million tons of unhulled rice per year with most of the land applying a one-time cropping index (Ratmini et al., 2019). The low productivity is due to various challenges, including land agrophysical, environmental, socioeconomic, and cultural issues. Increasing cropping intensity to twice a year and optimizing water and land management can increase rice productivity on tidal swamp.

Technology		**Variety of Rice**	**Result**	**Reference**
Cropping System	Rice varieties,	Inpari 34, and Margasari	There was an increase in rice productivity with the application of the rice cultivation technology package (Rice varieties, and one way flow micro water management)	Hatta et al, 2023
	Rice varieties, Rice-Tiger Shrimp Coculture System	Inpari 34 and Inpari 35	• Salt-tolerant rice varieties Inpari 35 and Inpari 34 can grow well on brackish water-induced land • The production of rice and shrimp was increase	Sahabuddin et al, 2024
	Rice Ratoon	Ciherang	The main crops cutting height on harvesting of 20-40 cm above the soil surface increases the number of productive tillers, grain weight per hill, yield per plot, ratoon ability to grow per plot, yield per plot and rice ratoon/main crops yield ratio per plot in tidal swamp by using direct seeding system.	Evriani et al, 2016
	Rice Varieties	IR64,and Inpari 4	• The treatment of two paddy varieties that were plant Inpara 4 varieties was better than the IR64 variety	Yartiwi et al, 2023
	Using superior rice varieties	Mekongga, Ciherang, Inpari 10, 13, 22, 31, 32, 33 dan 42, Inpara 1,3, 5, 7, and 9.	• Stress-tolerant and adaptive superior varieties may cope with high iron solubility and acidity of tidal swamp land.	Ratmini et al, 2019
Water Saving Tecchnology	One way flow micro water management	Inpari 34, and Margasari	There was an increase in rice productivity with the application of the rice cultivation technology package (Rice varieties, and one way flow micro water management)	Hatta et al, 2023
	Water Gate System	Impara 5	• water gate had caused water in tertiary channel was at maximum level of 80 90 cm which capable to continously increase Journal	Imanudin et al, 2019

			of Wetlands Environmental Management Vol 6, No 2 (2018) 93 - 111 http://dx.doi.org/10.20527/jwem.v6i2.165 of water table condition at land plot (zero runoff).	
	Water Management With Stationary SSC, Flow SSC, Stationary Conventional, Flows Conventional, fertilizer application (ameliorant : peat humic acid, dolomite, manure)	IR64,and Inpari 4	● The best treatment combination was SSC stationary + peat humic acid in terms of the number of productive tillers	Yartiwi et al, 2023
soil improvement technology	Ameliorant Substances	Impara 5	● Ameliorant substances were generally capable to increase pH value, to decrease iron concentration, but not all were capable to decrease sulphate concentration.	Imanudin et al, 2019

3.1 Rice Ratoon

Rice ratoon is a rice cultivation method that uses the remaining rice stumps to produce new shoots and tillers. These tillers can then be harvested and produce rice. In tidal swamp areas, rice productivity is still relatively low, so increasing it is a priority. Rice ratoon can be a solution to increase rice yields per season, while saving costs and labor.

The important success factor of rice ratoon is the cutting height of rice. This thing deal with the number of nodes. The number of nodes plays a crucial role in determining productivity as they give rise to lateral buds, which subsequently develop into ratoon tillers. The number of nodes directly impacts the potential number of ratoon tillers, with a higher node count increasing the likelihood of tiller emergence, thereby intensifying competition among tillers. Consequently, this factor significantly influences tiller production per hill.

The cutting height of rice can affect to rice plant growth. The higher cut of ratoon rice, the more productive tillers will emerge. Day to harvest also affected by the cutting height of rice. Day to harvest were faster on higher cut because they have shorter time on vegetative phase. The higher the cut of ratoon rice, the growth ability of ratoon and the yield of ratoon rice will increase (Mareza et al., 2016).

3.2 Rice-Tiger Shrimp Coculture System

In tidal areas, there is potential for brackish water intrusion, The brackish water-induced lands are abandoned by their owners because the land is unproductive, therefore technology is needed that can be applied so that the land continues to produce and increases production. One of them is coculture, which has often been applied between rice and ducks, rice and fish, but in brackish water conditions this technique is not yet effective. Technological innovations that are suitable for the conditions of this tidal ecosystem are rice and tiger shrimp.

The land was reconstructed using excavators into 70% rice fields and 30% caren for shrimp cultivation. This technique requires selecting varieties that are tolerant to salinity, namely Inpari 34 and Inpari 35. Inpari 34 and Inpari 35 rice varieties can be cocultured with tiger shrimp on the brackish water-induced land. Rice-tiger shrimp coculture system can be an alternative technology to restore land function that is intrusive by brackish water-induced land and support food security.

3.3 The Selection of Rice Varieties

The utilization of selection of the resistant varieties plays a crucial role in enhancing agricultural production due to various benefits such as shorter crop cycles, resistance to pests and diseases, and better tolerance to environmental stresses like immersion and high iron and aluminum solubility in acidic tidal swamp lands. The selection of crop varieties is a crucial factor influencing production, playing a significant role in boosting agricultural output, thereby contributing substantially to food security (Kamandalu *et al*, 2011). Climate fluctuations can also impact the pyrite layer content in such areas, affecting iron release and subsequently, crop growth. Despite the proven advantages, the development and adoption of superior varieties face challenges including limited seed availability, grain loss, market competition, and farmers' preferences. Strengthening regional breeding institutions and promoting awareness about the benefits of specific varieties are essential steps to address these obstacles and ensure widespread adoption.

3.4 Water management

3.4.1 Improving The Tertiary Canal Network

Improving the tertiary canal network could enhance water quality (by increasing pH and reducing iron) in the channels and tertiary plots in a tidal land to support rice production. Water retention had a significant impact on rice yield and water quality in the tertiary network. The retention of water in the tertiary network improved rice yield by providing sufficient water for the rice crop, similar to the results found in irrigation areas. Additionally, the water retention and the addition of ameliorant substances such as coconut fiber and sand cement blocks at the outfall of the tertiary and quarterly channels increased water quality by raising the water pH and decreasing the iron concentration. As a result, the rice yield increased from an average production of 2 tons/ha to 3 tons/ha.

3.4.2 Intermittent Irrigation and One-way Flow Irrigation

Intermittent and one-way flow irrigation can reduce iron toxicity in the newly-opened rice fields. High concentrations of iron in soil solutions can cause iron toxicity that can damage ice plants. Drainage and flooding for one week each; while in the rainy season, it needed 1-week flooding and 2 weeks of drying.

3.4.3 Saturated Soil Culture (SSC) Techniques

SSC techniques can reduce pyrite oxidation in tidal swamp land. The SSC technique increases growth, nitrogen activity, and nutrient availability. The stationary SSC, where water canals were made as deep as 30 cm, wide by 30 cm, and each bed was 3 m wide, and the water was allowed to stand still with a water level of 10 cm below ground level, and all floodgates were closed. The combination of a stationary SSC water management system with peat humic acid was found to be the best combination that resulted in the highest productivity. The IR64 rice variety, sensitive to Fe toxicity, was able to grow and produce similarly to the Inpara 4 variety, which is tolerant in tidal swamps with the water management system and ameliorant application. This technique improved plant biomass, nutrient absorption, soil pH adjustments, reduced soil Fe levels, and increased productivity.

3.5 Challenge of Tidal Swamp Rice Farming

Rice farming on tidal swamp land faces various challenges. One major challenge is water management. Tidal swamps experience fluctuating water levels due to tidal movements, which can affect plant growth. Water levels should be managed properly to ensure that rice plants receive adequate irrigation during both wet and dry seasons. The saline water intrusion further complicates water management, as excessive salinity can inhibit rice growth and yield (Imanudin et al., 2018). Low soil fertility, high iron and aluminum solubility, and the presence of pyrite are another challenge of tidal swamp rice farming (Ratmini et al., 2019; Yartiwi et al., 2023). The improper management of pyrite-rich land can lead to severe consequences, such as soil acidification and iron poisoning. High iron solubility can disrupt plant root growth and decrease rice production, even causing plant death in extreme conditions. This iron poisoning is getting worse in nutrient-poor soils, such as soil in tidal swamp land. Despite these challenges, tidal swamp rice farming can be utilized to ensure food security. These challenges can be overcome by implementing appropriate technology and management practices (Ratmini et al., 2019).

CONCLUSION

Tidal swamp areas present a promising opportunity for increasing food security in Indonesia. However, the suitability of tidal swamp land for agricultural extensification varies depending on factors such as soil salinity, water availability, and accessibility, soil fertility. This is a challenge in cultivating rice on tidal swamp land, therefore the technologies that can be applied to achieve food security include: rice ratoon, coculture system, the selection of rice varieties, and water management. All of these technologies are designed to maximize rice productivity in swamp areas. The integration of innovative technologies such as water-saving technology, cropping technology, and integrated fertilizer management can enhance rice productivity and contribute significantly to achieving food security in Indonesia.. There is a need for further experiments or research regarding the application of these various technologies in various tidal swamp land conditions so that they can be adopted in various areas with tidal swamp land types.

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