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REVIEWS **OPEN ACCESS**

Rice Cultivation of Superior Variety in Swamps to Increase Food Security in Indonesia

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ABSTRACT

The island of Java is Indonesia's largest rice production. However, the conversion of land into industrial areas and construction projects has contributed to the decline of rice production on the island. Therefore, it is necessary for the country to expand its agricultural site outside of Java island through the utilization of swampland. Indonesia has large areas of swampland, which have not made the most of it. The swampland farmers have never grown high quality of rice. Thus, the selection of high-quality rice is considered to increase rice production in the swampland. This article aims to discuss the rice cultivation of superior variety in the swamp to improve national food security. The result of this research showed that local farmers in the swamp area rarely adopt high-quality rice. In fact, local rice variety has low productivity and longer lifespan. Therefore, the use of the superior quality of rice is expected to boost rice production. Nevertheless, the Government of Indonesia has developed numbers of high-quality rice such as *Inpara* and *Inpari*, which are more adaptive in the swampland. The *Inpara* is more resistant to standing water for tidal swamps, while the *Inpari* is more suitable in *lebak* swamps (most of the year inundation). The use of *Inpara* and *Inpari* in swampland can increase rice production. The implications of rice cultivation of superior varieties increased productivity and crop index due to shorter rice life, resistance to pest and disease attacks, and tolerance of marginal environmental conditions. The use of superior variety can increase rice production, thus support food security in Indonesia.

Keywords

food security, rice, superior variety, swampland

1. Introduction

Rice is one of the food crops cultivated by most of the world's population. Asian countries dominate global rice production (Gadal *et al*., 2019), especially in Indonesia. The people of Indonesia in 2015 was 235,180,000 and is estimated in 2025 to be 284,829,000 (BPS, 2013). Rice consumption increases every year, as the population increases (Suryani *et al*., 2016). Rice is a daily staple for about 95% of Indonesia's population. Rice has also been a strategic political commodity since the beginning of independence. The Government of Indonesia has gone to great lengths to increase rice production for national needs (Swastika *et al*., 2007).

Rice crops become a strategic commodity in economic, social, and political aspects because they support agricultural programs (Jumakir *et al*., 2014). Indonesia is known as an agricultural country. The farm sector is relied upon to support the country's economy. Since 1984, Indonesia has been a national rice self-sufficiency country (Maulana *et al*., 2017). Rice fields are the primary source of rice production. The island of Java is the center of rice production in Indonesia. However, the area of fertile rice fields in Java is narrowing because of

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converting productive land functions to non-agricultural sectors, which rapidly diminished rice production (Swastika *et al*., 2007). The conversion of farmland to non-agricultural use will threaten national food security (Elizabeth and Azahari, 2019). In 2019, Indonesia's rice harvest area was 10.68 million ha, and the recorded decrease was of 700.05 thousand ha (6.15%) compared to 2018. In 2019, rice production was 54.60 million tons of dry grain and decreased by 4.60 million tons (7.76%) compared to 2018. Rice production in 2019 was 31.31 million tons or decreased by 2.63 million tons (7.75%) compared to 2018 (BPS, 2020).

The island of Java contributed to 60% of national rice production. The conversion of agricultural land undermines the availability of food and Indonesian food security. The growing population requires a proper solution for decreasing agricultural land. Therefore, the utilizing of swampland outside Java Island for growing superior rice is considered the best solution. The application of technology through the cultivation of a superior variety of rice is expected to replace the less productive of the local type. Considering the crucial role of rice production to Indonesian food security, The Government of Indonesia has provided an alternative to the issue through the innovation of rice varieties, which are more adaptive to the Indonesian swampland.

2. A superior variety of rice

Local rice variety dominates nearly 90% of rice cultivation in tidal swampland. This local rice is more widely grown because it is stagnant tolerant. On the other hand, however, the harvest period takes longer (8–10 months) and low yield (2.0–2.5 tons/ha) (Koesrini *et al*., 2018). Local rice cultivation has been an integral part of the local culture and traditions of the local community for generations. Indonesia has 40 local rice cultivars with different morphological characteristics. Currently, those local rice variety is still preserved by farmers around swampland (Mursyidin *et al*., 2017).

Local variety has resistance to bacterial leaf disease, citrus leaf disease, brown planthoppers, leaf explosions, neck explosions, white striped leaves, and drought. Still, they are prone to Al, Fe, and abiotic stress (salinity, cold temperature, and shade). The use of local variety is recommended as a master hybridization to obtain specific genotypes that excel at new types. Thus, the released varieties have a broad genetic diversity (Sitaresmi *et al*., 2013).

The genetic resources are available at the Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development (ICABIOGRAD), and International Rice Research Institute (IRRI) can use to develop superior varieties. At present, accessions collected in the ICABIOGRAD gene bank are 3,563 cultivated rice plants and 100 wild rice species. The Indonesian government has released more than 160 types of rice for lowlands, highlands, and tidal swamps (Silitonga, 2004). The use of superior variety potentially has higher production, is resistant to pests and diseases, and is tolerant to abiotic problems (Jamil *et al*., 2016).

The rice cultivation on swampland is carried out gradually. Rice plants can only be planted once a year during the dry season in swamp after the water in the shallow *lebak* begins to recede. Then the middle and deep swamps follow the planting. Thus, the use of an adaptive variety of rice in swampland is one of the essential efforts. It is necessary to increase rice production, resistant to pests and major diseases, and has good rice quality (Waluyo and Suparwoto, 2017). The rice variety is tolerant of global climate change in tidal swamps through superior and local crossbreeding. There are five cultivars found, namely *IR 102860-8: 66-BB, IR 102860-8:42-BB, IR 101465-8:23, IR 101465-5:25*, and *B13522E-KA-5-B* with high yield potential to deal with climate change. The best comparison is *Inpara 9*. This variety has high parameters of the number of productive puppies and short seeds that have similarities with the character of *Inpara 9* (Lestari *et al*., 2019). Successful rice production in swampland requires planting materials from superior variety adapted to the environment or ecosystem (Chozin *et al*., 2019).

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However, the development and adoption of technological innovation by farmers are not accessible. Superior variety utilizes the advantages of heterocyst from rice crops, namely F1, which provides performance beyond both parents (Ruskandar, 2010). Crossbreeding between traditional rice cultivars as parent stock can produce a new superior variety that is more adaptable to swamps. There are two superiors adaptive in swamplands, namely *Inpara* and *Inpari*. The *Inpari* is an acronym from *inbrida padi sawah irigasi* (Indonesian) or inbred irrigation rice fields (English) and has a varying age between 99–125 days. Still, *Inpara* is an acronym from *inbrida padi rawa* (Indonesian), or inbred rice tidal swamps (English).

The education, counseling, and availability of superior seeds play an important role in adopting a superior variety of rice. In line with the statement, Ghimire *et al*. (2015) asserted that the use of selected varieties could anticipate hunger and food insecurity in developing countries. According to Lema (2018), the application of biotechnology improves the quality and quantity of rice production through the transfer of essential properties. Besides, it can also help reduce the cost of rice cultivation and increase nutritional value. Biotechnology can protect the environment and natural resources.

The rice character of superior variety has higher yield potential, can adapt to the environment of swampland, and is resistant to pest attacks and diseases (Sasmita *et al*., 2019). Superior variety has resistance to biotype two brown planthopper pests, path type III, and brass leaf disease, and are tolerant of Fe and Al poisoning (Danial and Sulhan, 2017). Superior variety is a significant component of technology that can contribute to increased rice production.

The Ministry of Agriculture has released 11 rice varieties for swampland since 2008–2019, namely: *Inpara 1, Inpara 2, Inpara 3, Inpara 4, Inpara 5, Inpara 6, Inpara 7, Inpara 8 Agritan, Inpara 9 Agritan, Inpara 10 BLB*, and *Purwa* (Sasmita *et al*., 2019). Based on recent literature, there are some varieties of *Inpari* and others that are adaptive to cultivate on swampland. The use of superior variety is an effort to accelerate the development of rice that has great pretension to support food self-sufficiency.

3. Swamp in Indonesia

Lo Indonesia has about 33.43 million ha of swampland, consisting of 13.3 million ha of swamp and 20.1 million ha of a tidal wetland. Swampland spreads across in Sumatra, Kalimantan, Papua, and Sulawesi. The map of swampland spread in Indonesia was presented in Figure 1 (Maftu'ah *et al*., 2016). There are two types of swampland in Indonesia: tidal and *lebak* swamp (Sulaiman *et al*., 2019). The development of tidal and *lebak* swampland is a strategic step and an alternative solution to increase food production and offset agricultural land losses. The opportunity to develop swamp as a source of agricultural produce is still quite broad, either from the availability of land that has not been or has been managed. In general, swampland in Indonesia has not been optimally used and developed.

Swampland is marginal and fragile land. Hence, the technical aspects are the principle for selecting technology applications. Socio-economic issues play a potential role in the success of agricultural development on swampland. Use of swamp for agriculture through three stages. The first is the identification and characteristics of the marsh as the basis for determining development priorities based on technical and socio-economic aspects. The second is to select land, water management technology that corresponds to soil typology and overflow. The third is the selection of suitable agricultural commodities (crops, livestock and fish) both from technical and economic aspects (Suriadikarta and Sutriadi, 2007).

In general, the nature of swampland has an acidic pH (4–4.5), the texture is a high fraction of clay and dust, a slight fraction of sand, and low Ca, Mg, K and Na. Swampland is less than optimal land with low productivity due

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to acidity, malnutrition, and high toxic (Al, Fe, and H_2S) (Kodir et al., 2016). The content of microelements such as Al, Fe, Mn, B, and S is relatively high in swampland. High Al and Fe content causes soil reactions to become highly acidic, and soil pH is low (Helmi, 2015). Iron poisoning (Fe) in rice crops can cause barriers to growth, seeding, and grain filling. The distribution of iron concentrations varies in various swampland locations, so the side effects of iron poisoning on rice crops also vary. The highest Fe concentration occurs in areas close to the in waterways. Rice seedling planting must reach a depth layer of more than 10 cm to produce optimal rice production (Mawardi *et al.*, 2020). The characteristics of bronzing indicate iron toxicity in plants. Higher iron uptake by plants decreased protein synthesis in the leaves (Rout and Sahoo, 2015)

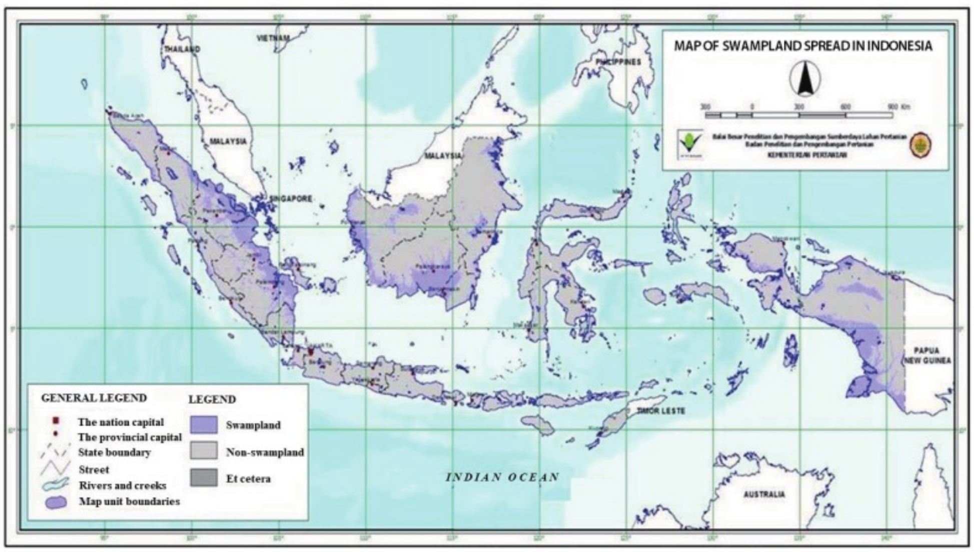

Figure 1: Map of swampland spread in Indonesia

Inpara 3, Inpara 4, and *Inpara 5* have unique characteristics compared to other rice varieties. *Inpara 3* can survive after seven days of immersion, while *Inpara 4* and *Inpara 5* can last 10–14 days. *Inpara 3* is tolerant of water immersion, so it is suitable for swampland with water fluctuations in this agroecosystem varies greatly. *Inpara 3* is an appropriate variety for flood-prone irrigation land. *Inpara 1, Inpara 3*, and *Inpara 7* are tolerant of iron poisoning (Fe) and aluminum (Al), which are essential obstacles in developing rice crops in tidal and *lebak* swamp.

3.1 Tidal swampland

The tidal swampland is one of the marginal lands that can replace fertile land in Java (Wakhid and Syahbuddin, 2019). Tidal water in swampland is affected by tides or seawater flows or rivers, while *lebak* swamp is affected by rainwater (Sudana, 2005). The characteristics of agricultural land in Java are very different from the swamp. The right agrarian system can accommodate unique environmental conditions. Tidal swampland has less fertile, irrigated, and acidic soil (Yanti *et al.*, 2003).

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The area of tidal swampland in Indonesia is estimated at around 20.1 million ha, spread across Sumatra, Kalimantan, Papua, and Sulawesi. The tidal swampland that has been used for 9.53 million ha for rice cultivation and is a new source of rice production (Suwanda and Noor, 2014). The area of tidal swampland in Indonesia is approximately 34.93 million ha (18.28%) terrestrial regions of Indonesia. The map covers 12.93 million ha of Sumatra, Java 0.90 million ha, Kalimantan 10.02 million ha, Sulawesi 1.05 million ha, Maluku and North Maluku 0.16 million ha, and Papua 9.87 million ha (BPPP, 2019). The Ministry of Agriculture seeks to increase food production, especially rice nationally. The total tidal land area in Indonesia is 20.11 million ha. The land can be a source of rice production, but only 9.53 million ha is utilized. If 50% of the land could be used for rice cultivation, it would produce about 14.295 million tons of dry grain per year (Mamat and Noor, 2018).

Swampland potentially can be developed as agricultural land, especially for the cultivation of rice crops. However, the utilization of tidal swamps and freshwater or *lebak* swamp has not been optimal. The obstacles are low land productivity, low farmer education, lack of infrastructure, and pest attacks are still high. The application of technological innovation, quality of human resources, and institutional support is a significant opportunity to develop swampland (Susilawati and Rumanti, 2018). Rice planting time in tidal land can be increased from once to twice/year in three climatic conditions. The utilization of potential tidal swampland occurs in reduced water conditions, although not too different from wet and standard shapes (Wakhid and Syahbuddin, 2019).

Local farmers have maintained agricultural systems on tidal swampland for hundreds of years. They have the knowledge and experience to overcome the various obstacles and problems associated with the cultivation of this land. Traditional rice cultivation systems for agricultural practices have maximized existing natural resources (Yanti *et al*., 2003). Increasing the contribution of rice supply from Central Kalimantan through productivity improvement, intensification, extensive, and yield safety. The safety of crops can be improved through tolerant rice varieties, water management, fertilization, land management, pest and disease control, and improved socio-economic aspects of farmers (Irwandi, 2015).

In tidal swampland areas, waterway systems are useful for regulating the availability of water on land into primary, secondary, tertiary, and quaternary canals. Proper management of water availability in swampland allows in one year to three times harvest. The first harvest season starts in November-February, only able to grow rice. The second harvest season is in March–May for rice crops and other highland food crops, such as corn and soybeans. The third harvest season in June–August (dry season) can cultivate highland food crops due to limited water availability (Irmawati *et al*., 2015).

Increasing rice production in tidal swamp areas has potential and promising prospects due to the support of the right technology, human resources, land, and agroecosystems. Integrated plant management is a technology implementation approach to support increased rice production. Rice production increased from 4.0 to 7.04 tons/ha (Jumakir and Endrizal, 2014).

The development of new superior variety needs consideration regarding location specifics and farmers' preference for rice crop characteristics. The productivity of excellent types has a yield range of more than 6 tons/ha of the dry grain harvest, contributing to increased rice production (Adri and Yardha, 2014). The government has mostly removed superior variety for swampland so that farmers can choose the type that suits their territory. It will expand the genetic diversity of plants in the field to reduce the risk of explosions of certain pests and diseases (Waluyo and Suparwoto, 2017).

Tidal swamps in Indonesia have great potential for inbred and hybrid rice cultivation. However, for one year can only grow rice once. Increased land productivity can be through rice cultivation with a ratoon system after harvest (Susilawati and Purwoko, 2018). Tidal swampland utilization has considerable opportunities to support the

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above programs. Support a wide range of technological innovations, such as water and soil management, landscaping, fertilization, adaptive and productive superior variety, and agricultural equipment and machinery to take advantage of opportunities (Arsyad *et al*., 2014).

Inpara 2 and *Inpara 3* produce dry grain of 4.04 tons/ha or 35% higher than the *Margasari* variety. It indicates a useful adaptation in tidal swampland. *Inpara 1* and *Inpara 6* are 2,118 and 2,275 tons/ha of dry grain or 1.9 and 9.5% higher than the *Ciherang* variety. It shows an excellent adaptation of *Inpara* in swampland (Koesrini, 2018). The results showed five types, namely *Inpara 1, Inpara 2, Inpara 3, Inpara 4, and Inpara 5*, with *Mekongga* and *Batanghari* variety comparisons. Rice growth shows that *Inpara 2* has the highest crop posture compared to other superior varieties and comparators. *Inpara 1* obtains the highest number of puppies. *Inpara 2* and *Inpara 4* provide higher results than the two comparative types. Rice development in tidal swampland in Merauke Regency is more suitable using *Inpara 2* and *Inpara 4* (Lestari and Kasim, 2014).

South Sumatra has good enough potential for rice farming development in tidal swampland. Rice of *Inpara 1, Inpara 2, Inpara 3, Inpara 6, Inpara 7*, *Agrarian 8*, and *Agrarian 9* are adaptive varieties. Banyuasin regency is a contributor to rice production of 26.41% or 1,305,533 tons of dried grain harvested in 2017, resulting in a surplus of 733,352 tons (Hendrik, 2018). Central Kalimantan has an area of tidal swamps of about 5.9 million ha. About 0.81 million ha is suitable for rice production, thus contributing highly to the availability of rice. No more than 10% of swampland has been used for rice cultivation (Irwandi, 2015).

The development of ratoon rice cultivation in tidal swampland can use hybrid variety. During harvest, the stem of the staple plant is cut 20 cm from the ground level and fertilize with urea 100 kg /ha. Ratoon plants have appeared 5–6 days with 2-4 leaves and 5.5–26.0 puppies per clump. The average age of ratoon harvesting is 69 days from cutting stems. Ratoon produced an average of 75.2% of the yield of staple crops. Grouping rice crops into three parts from a high, medium, and low production. The first groups were *Hipa 3, Hipa 4, Hipa 5, Maro, Rokan, Ciherang*, and *Sintanur* variety produced more than 2 tons/ha. The second groups were *Hipa 6, IR42, Margasari*, and *Mekongga* variety made 1–2 tons/ha. The third was the Batanghari variety produced less than 1 tons/ha (Susilawati and Purwoko, 2018).

3.2 *Lebak* swampland

Lebak swampland is an area affected by river flooding, not by seawater so that at the end of the rainy season can only be rice. Classification of *lebak* swampland into three categories based on topography and length of puddle time. First, the shallow embankment is a swampy area with relatively high topography and short puddle time. Second, the deep swamp is an area located away from the shallow *lebak* and is a basin that regularly contains water. Third, the central swamp is an area situated between the deep swamp and the shallow embankment (Sulaiman *et al*., 2019).

Lebak swampland is characterized as always stagnant in the rainy and dry seasons in the dry season. There were three types of *lebak* swamp: 1) shallow *lebak*, in the rainy season with a height of 50 cm for three months, 2) central *lebak*, water level between 50–100 cm for 3–6 months, and 3) deep puddles for six months. Shallow *lebak* can be planted with rice and other food crops, while the deep *lebak* is only suitable with higher local rice (Suriadikarta and Sutriadi, 2007).

The main problem of swampland is the high flooding in the rainy season and drought in the dry season with flood conditions (Waluyo *et al*., 2008). In general, farmers can grow rice in this swampland only once a year during the dry season. Rice cultivation is carried out after the water in the swamp begins to recede and is then followed by the central and deep swamps. The use of adaptive rice variety in swampland is one of the essential efforts that need to make higher productivity, resistant to pests and major diseases, and have good rice quality (Suparwoto and Waluyo, 2019).

Causes of low productivity of swampland are low soil fertility, 5–6 months local variety, and conventional land management. The main obstacles in developing swampland are unpredictable inundation and drought and depend on the topography of the hydro, rainfall, and water levels of local rivers (Helmi, 2015). If the evapotranspiration value is higher than the rain, it will cause drought conditions. The amount of evapotranspiration is not affected by rainfall, but by the area of land cover. Rainfall, tides, rivers, and runoff affect water availability (Puspitahati *et al.*, 2017).

The total area of swampland in Indonesia is 13.27 million ha. The new public or private sector is utilizing an area of 4 million ha. A place of 2.6 million ha is managed by the public and private sector, while 1.3 million ha is government assistance (Muhakka *et al.*, 2019). Rice planting on *lebak* swampland is only about 694,291 ha (5%) of a total area of 13.2 million ha. *Lebak* swamp can only be planted rice once in South Sumatra Province (148,979 ha), Central Kalimantan (114,500 ha), and West Kalimantan (102,200 ha). Other Provincial regions average less than 100,000 ha. Lebak swampland that can be cultivated rice twice a year, namely in Riau Province, South Kalimantan, West Kalimantan, and Central Kalimantan with an area of more than 10,000 ha each, but other provinces average less than 10,000 ha. The progress of land use for agricultural businesses is still low, so it still has excellent opportunities as a source of agricultural growth (Sudana, 2005). Swampland of 11.64 million ha is low terrestrial, except in Sumatra, about 0.03 million ha (BPPP, 2019).

The development of tidal swamps for agriculture requires land and water management and technology to get optimal results. The acceleration of agricultural development in tidal swampland can be through four subsystems, namely land development, cultivation development, mechanization, and post-harvest, as well as. The innovation can be used as a foundation to develop the acceleration of agriculture in swampland (Effendi *et al.*, 2014). Proper water availability control in the tidal swamp can increase the rice-planting period three times a year. The first season will start from November–February to grow rice per year (Wildayana and Armanto, 2018).

In 2012, the area of *lebak* swamp in Lampung Province reached 55,714 ha with a rice productivity level of 5.13 tons/ha and still has the opportunity to be improved. Rice production can be increased through increased land productivity and crop index, reducing yield gaps, and reducing yield losses. This increase in production will have an impact on improving food availability, both regionally and nationally (Pujiharti, 2017).

The use of new superior variety in swampland can increase rice production. *Inpara* and *Inpari* can grow and thrive in shallow and central marshlands. In the shallow swamp, it is better to use drought-tolerant varieties such as *Situbagendit, Limboto, Batutegi, Inpago, Inpari-1, Inpari-4, Inpari-6*, *Inpari-6*, and *Inpara-5*. In the deep swamp, only once a year can grow rice. The use of superior variety resistant to immersion can use *Inpara-3, Inpara-4*, and *Inpara 5* (Suparwoto and Waluyo, 2019).

Higher rice productivity is produced by *Inpara 1, Inpara 2*, and *Inpara 3* than other swampland rice varieties. Likewise, the *Mekongga* variety can still provide good productivity in lowland swamplands (Helmi, 2015). Rice production of 4.9, 6.8, 6.1, and 7.0 tons/ha of dried grain is produced *by Inpari 15, Inpari 22, Inpari 30*, and *Inpara 4*. The use of *Inpari 22, Inpari 30*, and *Inpara 4* is worth developing as it is financially profitable (Guwat *et al.*, 2015). The optimal fertilizer dose in *lebak* swampland per ha for *Inpara 3* variety is 300 kg urea, 50 kg SP-36, and 150 kg KCl (Rois *et al.*, 2017). Rice production of *Inpari 9* and *Inpara 4* is higher than the *Mekongga* and IR42 variety in *lebak* swamp (Suparwoto, 2019).

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4. Conclusions

The island of Java is Indonesia's center of rice production. The conversion of agricultural land to industrial and residential construction declines rice production. It is necessary to expand agricultural sectors outside Java island through the utilization of swampland. Local farmers around the swampland are still low in adopting a superior variety of rice. Local farmers around the swamp are still low in adopting a superior variety of rice. The local rice variety has low production potential and longevity. The government has developed many rice varieties that are adaptive in the swampland environment. *Inpara* and *Inpari* are a superior variety for swampland. The *Inpara* is more resistant to standing water for tidal swamps, while the *Inpari* is more suitable in *lebak* swamps. The types of rice variety that have been developed by the government have been planted by swamp farmers in several places and have high yields. However, only a few farmers are willing to adopt this technology. Therefore, it is necessary to promote superior rice cultivation to swamp farmers. The rice cultivation of superior variety in the swamp has provided higher rice production. The use of superior varieties of rice with a shorter lifespan can increase the crop index to three plantings in one year. Hence, it is recommended that all farmers in swampland areas can adopt this superior variety, automatically increases rice productivity, and strengthen national food security.

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