Factors affecting rice yield productivity in tidal swamp of South Sumatra

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Abstract. Agricultural land expansion in tidal swamp rice (Oryza sativa L.) has not been optimally utilized. The objective of the study was to examine the relationship between soil, climate, and other factors that affect rice productivity. The study was conducted in Muara Telang Sub-district and used the purposive sampling method from 30 respondent farmers. The results showed that rice production was lower in the dry season (DS) than wet season (WS) ($r^2=0.96$) which was closely related to water availability. A low percentage of total pore space (TPS) and availability of P$_2$O$_5$ have an impact on rice yield in WS while rice yields at DS 2019 are directly related to N applications. Low temperatures have a positive impact on the presence of $C_{naphalocrocis medinalis}$ and $G_{ryllotalpa brachyptera}$ but high humidity has a major impact on the presence of $R_{attus argentiventer}$ and $B_{acterial leaf blight}$. On the other hand, the income received by farmers is doubled in WS compared to DS (R/C ratio 2.4 Vs. 1.2). Nutrient management, soil pore space, and climate information can affect rice productivity in tidal swamp rice fields that are economically beneficial in WS, however further research is needed for DS condition.

1. Introduction

Indonesia is the 3rd rice producer and the first largest consumption in the world [1]. Currently, Indonesia's productivity has decreased by 1.71% from 2018 to 2019 [2] which is a challenge in realizing Indonesia as a world food barn in 2045. The government has implemented extensification of agricultural program by opening new paddy fields since 2014 covering an area of 40,000 ha [3]. One of the provinces to receive this program is South Sumatra, which is followed by the program called ‘the safe the swamp and increased farmer prosperity (Serasi) that covered 400,000 ha in three provinces, namely South Sumatra, South Kalimantan and South Sulawesi [4].

Prior to the 2014 rice opening new paddy fields program, South Sumatra was the 5th rice producer. The extensification program using tidal swamp rice land has an impact on increasing production, which peaked in 2016 of 35.5% compared to 2010. In contrast to 2019, there was a decline in production of 48.7% with an average productivity of only 4.8 t ha$^{-1}$. According to Raharjo and Hernewita [5] the factors that cause decreased productivity are land degradation, environmental damage, climate change, and low human resources.
Research result by Waluyo et al [6] showed the potential for lowland swamp in South Sumatra is 13 million ha. The limiting factor of tidal swamp rice is low soil fertility [7], P deficiency, low exchange rate [8], high soluble Al, and low soil pH [9]. This is evidenced by the average production of farmers in swampy tidal land of only 2.7 to 3.0 t ha⁻¹ [10] below the average national production of 5.1 t ha⁻¹ [2].

In addition to soil factors, climate change results in changes in rainfall and temperature patterns [11] which results in stress on plants in the form of heat, salinity, drought, and submerge [12] which in turn has an impact on rice yield fluctuations by 32% or the equivalent of an annual loss of 3 million tons [13]. Climate change also affects the attack of pests and diseases. Based on Peace [14], pests and diseases last longer in the dry season due to warm temperatures. The loss of food crop yields is 40% due to pest attacks [15].

On the other hand, human resources are also important in increasing rice productivity. According to Raharjo and Hernewita [16], there is insignificant relationship between the level of farmers' knowledge and the implementation of farmer technology in tidal swamp rice. Apart from the problem of technological innovation and institutional support, the farmer education factor is also a problem in tidal swamp rice [17]. It needs to conduct research aimed at: 1. To examine the relationship among soil, climate, and other factors affecting the rice productivity in tidal swamp rice; and 2. To determine the benefit of tidal swamp rice farming.

2. Materials and methods

2.1. Experimental site

The research was conducted in July to December 2019 in Sumber Hidup Village (2° 40' 26.67" South latitude and 104° 51’ 32.76" East Longitude, elevation 1.25 to 1.50 m.a.s.l.) and Telang Makmur (2° 41’ 28.82" South latitude and 104° 53' 23.64" East Longitude, elevation 1.50 to 1.75 m.a.s.l.), Muara Telang Sub-district, Banyuasin Regency, South Sumatra. Soil types in the study area were Fluvaquentic Endoaquept, very fine, mixed, semiactive, acid, isohyperthermic [18].

2.2. Research design

This study used purposive sampling method in collecting farmer data and soil sampling of 30 respondent farmers. Data collection used a questionnaire covering technical, socio-economic, institutional and accessibility aspects which functioned to obtain individual information and problems faced by farmers. The selected farmers are farmers who are in Type B (12 farmers) and C (18 farmers), have more than 10 years of experience in rice farming, planting index 2 to 3 (rice-rice-food crops/fallow), and assisted farmers of ALAT South Sumatra in the Serasi program. Soil variables observed for soil chemistry for a depth of 30 cm include pH H₂O, C-Organic, N-total, P₂O₅ and K₂O HCl, cation exchange capacity (CEC), exchange bases such as exchangeable K, Na, Ca, Mg, and base saturation while soil physical properties such as bulk density (BD), total pore space (TPS), permeability (Ksat), and texture.

2.3. Soil analysis

Analysis of the chemical and physical properties of the soil was carried out at the Indonesian Soil Research Institute (ISRI) and Sriwijaya University in 2019 by taking four points in each farmer and then composing. Water permeability (Ksat) was measured using a double ring at each direct treatment at the study site until it reached a stable condition. [19]. Soil texture using the pipette method, soil density (g cm⁻³) with soil sampling using the ring sample method, and pore space filled with water was determined using the equation according to Linn and Doran [20].

Soil chemical analysis such as pH analysis; C-organic; N-total; P₂O₅ and K₂O available; Exchange cations (Ca, Mg, Na, K) and CEC; as well as family planning using the respective pH meter methods; Walkley and Black; Kjehdahl; Bray I; Morgan; Ammonium acetate 1 N pH 7.0; and the calculation of the number of
bases divided by the CEC then multiplied by 100. Composite soil samples were taken randomly at four points from 0 to 0.30 m. The soil categories based on Eviati and Sulaeman [21].

2.4. Data analysis
Primary data analysis obtained from survey data and soil analysis tabulated into excel. To answer the first objective, it is processed using statistical analysis tools for agriculture research (STAR) and the second goal is using MS. Excel. Pearson's correlation coefficient for parameters measured using STAR. Significance at the 0.05 probability level; 0.01; and 0.001 are indicated by *, **, and ***, respectively. Agronomic costs are analyzed by comparing income to costs (R/C ratio). Secondary data is in the form of climate and pest and disease data produced by [22] and [23] for the last 8 years.

3. Results and discussion

3.1. Land typology and soil fertility
Tidal swamp is directly affected by marine activity with a sedimentation process where the land is formed as part of the river delta [24]. The research location is tidal swamp area which includes type B and C (Sumber Hidup Village) and type C (Telang Makmur Village). According to agricultural extension agencies data from Muara Telang Sub-district, the total area of land cultivated by farmers in Sumber Hidup Village is 1.688 ha while Telang Makmur Village covers an area of 1600 ha. Based on Arsyad et al [8] and Masganti et al [25] the characteristic of type B is that it gets an overflow at high tide, while type C does not receive overflow but the depth of groundwater table is <50 cm.

Table 1. Chemical analysis of tidal swamp rice soils in Muara Telang Sub-district, Banyuasin Regency, South Sumatra.

| No. | Type of analysis | Method of analysis | Value | Category*) |
|-----|-----------------|--------------------|-------|-------------|
| 1.  | pH (H2O)        | pH meter           | 4.60  | Acid        |
| 2.  | Organic-C (%)   | Wakley & Black     | 5.60  | Very high   |
| 3.  | N-total (%)     | Kjeldahl           | 0.43  | Medium      |
| 4.  | Available P2O5 (ppm P) | Bray I | 265.7 | Very high |
| 5.  | Available K2O (ppm K) | Morgan | 254.8 | Very high |
| 6.  | Ca-dd (me100 g⁻¹ soil) | NH4OAc 1.0 N | 3.40  | Low         |
| 7.  | Mg-dd (me 100 g⁻¹ soil) | NH4OAc 1.0 N | 2.98  | High        |
| 8.  | Na-dd (me 100 g⁻¹ soil) | NH4OAc 1.0 N | 0.90  | High        |
| 9.  | K-dd (me 100 g⁻¹ soil) | NH4OAc 1.0 N | 0.60  | High        |
| 10. | Base saturation (%) | NH4OAc 1.0 N | 22.72 | Low         |
| 11. | CEC (me 100 g⁻¹ soil) | NH4OAc 1.0 N | 34.00 | High        |
| 12. | Texture         | Pipet              |       | Silty clay  |
|     | Sand (%)        |                    | 0     |             |
|     | Silt (%)        |                    | 49    |             |
|     | Clay (%)        |                    | 51    |             |

*) Categories based on Eviati and Sulaeman [21].

The results of soil analysis showed that soil pH is in the acid category, organic-C content and available P2O5 is very high categories, the content of Mg-dd, Na-dd, K-dd and CEC is high, it is inversely to the content of Ca-dd and base saturation (BS) is in the low category, while the total N content is in the medium category. Soil acidity that occurs is due to land drying, especially in the dry season [26] which results in
pyrite oxidation [27,28], high iron solubility, and availability Low P and K [18,29,30]. The available P and K nutrient content is very high (table 1.) due to the return of straw and P fertilizer residues. The results of the 2019 survey showed that farmers applied P₂O₅ fertilizer in various amounts of 37.5 to 135 kg ha⁻¹. This was done in WS and DS in the hope of an increase in production in the DS. The reality faced by production farmers is two times higher in WS compared to DS [31].

In general, soil fertility at tidal swamp land is low [8,25,31]. However, the 2015 to 2019 government program in distributing agricultural machine tools such as the combine harvester, 1-ton ha⁻¹ lime, and bio decomposer has an impact on increasing soil fertility. Harvesting using a combine harvester directly returns all rice straw without being transported. This is evidenced by the results of soil analysis in table 1. All categories are included in the medium-very high category except for Ca-dd and BS. The provision of organic rice straw can increase the availability of P, K, Ca, and Mg nutrients (, improve soil physical properties and increase rice productivity [32,33,25], soil N availability [34], and CEC [18]. Furthermore, the soil texture in the study location was silty clay. In accordance with the research of Prasetyo et al [18] the texture in Banyuasin is clay to silty clay texture with a high content of clay fractions (>50%). Increasing clay content can increase soil fertility [35] and rice yield [36].

3.2. Rice planting conditions
The cropping pattern of two villages is rice-paddy/fallow-fallow/corn/vegetables/melon. In both growing seasons, direct seeded rice was planted in rice to avoid stress at the beginning of seed growth due to water and limited labor. Labor problems [37], capital, farmers’ mastery of technology [8], lack of government attention in maintaining macro water system networks, and underdeveloped rural institutions are important problems in tidal swamp rice [38].

Table 2. Cropping practices, soil management, and climate for the last two years in Muara Telang Sub-district, Banyuasin Regency, South Sumatera.

| Parameter | 2017/2018 | 2018 | 2018/2019 | 2019 |
|-----------|-----------|------|-----------|------|
| Commodities | Rice | Rice | Rice | Rice |
| Varieties | Inpari 30, 32, 42, dan 43 |
| Cropping pattern | Rice-paddy/fallow-fallow/corn/vegetables/melon |
| Land management | Dry |
| Farming techniques a) | Dry seeded rice |
| Planting date | 19-Oct-17 | 01-March-18 | 12-Oct-18 | 23-Feb-19 |
| Harvesting date | 15-Feb-18 | 28-Jun-18 | 8-Feb-19 | 21-Jun-19 |
| Production (t ha⁻¹) | | | | |
| Type B | 7.4 | 3.0 | 7.3 | 3.0 |
| Type C | 6.1 | 2.9 | 5.9 | 3.0 |
| Total rainfall (mm) b) | 1052.6 | 1058.0 | 1011.2 | 1099.2 |
| Mean Temperature (°C) c) | 27.5 | 27.5 | 27.5 | 27.7 |
| Humidity (%) d) | 86.1 | 87.0 | 90.1 | 90.3 |

a) dry seeded rice without flooding.  
b, c, d) climate data from BMKG South Sumatra per season.

Furthermore, rainfall plays an important role in crop growth and production in both locations. South Sumatra BMKG data for 2017 to 2019 shows that the number of rainy days in the four seasons is 74 to 76 days. The average rainfall throughout the season during the rainy season (WS) is ≥13 mm per day until
flowering, but at the time of maturation the seeds are only 7 mm per day. Furthermore, the rainfall in the dry season (DS) is $\geq 15$ mm per day at the beginning of plant growth, but at the time of flowering the amount of rainfall is only 7 mm per day. The high rainfall on WS resulted in an overflow of river water (fresh water) which filled the upper layer, whereas in DS, which was initially high, then flowering began to be filled with sea water (salt water), thus affecting production. Table 1 shows the average production in WS is two times higher than in DS. Tidal swamp rice is very suitable for rice plants as long as there is enough water available throughout the season [39] with a water requirement of 2,500 liters including evapotranspiration, seepage, and percolation to produce 1 kg of rice [40]. On the other hand, the average temperature in DS and WS were almost the same, while RH in WS 2018/2019 and DS 2019 was higher than the previous season.

3.3. Relationship of soil, climate, and other factors

The mean soil physics and farmers method of tidal swamp rice in Muara Telang Sub-district, South Sumatra are shown in table 3. The dominant of mean clay percentage is 46.8% and mean rice yield in WS is higher 42% than dry season. Furthermore, the high variation of sand content between types B and C is 0 to 30% with a high CV variation of 44 to 75 affecting the Ksat variation of 4 to 13 mm h$^{-1}$ (CV 28 to 36). Girsang et al [41] reported that BD and Ksat are good indicators of projecting rice yields on aerobic soil. Likewise, the variation of K$_2$O fertilizer application for farmers was 15 to 180 with the highest CV 41 to 83 on both MH and MK. Another thing is the mean cropping index (CI) of 2.7 with a CV of 17, the range between types is 15-19. Agricultural mechanization plays an important role in increasing CI in addressing labor problems [42]. The availability of agricultural mechanization and changes in soil fertility (table 1) with the Serasi program in South Sumatra is very beneficial for farmers, but farmers must be able to change their habits in operating fertilizer tools and applications according to crop needs and yield targets.

| Parameter          | Mean  | Min  | 25%  | 75%  | Max  | CV among field† |
|--------------------|-------|------|------|------|------|-----------------|
| Sand, %            | 17.2  | 0.0  | 9.0  | 25.0 | 30.58| 57 (44 to 75)   |
| Silt, %            | 36.0  | 13.5 | 31.3 | 40.2 | 49   | 22 (18 to 27)   |
| Clay, %            | 46.8  | 35.5 | 39.7 | 51   | 78.7 | 18 (13 to 22)   |
| BD 0 to 0.3 m, g cm$^{-3}$ | 1.02 | 0.72 | 0.97 | 1.14 | 1.30 | 14 (13 to 14)   |
| BD 0.3 to 0.6 m, g cm$^{-3}$ | 1.05 | 0.79 | 1.02 | 1.12 | 1.20 | 10 (8 to 10)    |
| TPS 0 to 0.3 m, %  | 63.5  | 52.7 | 58.7 | 64.7 | 74.4 | 9 (8 to 9)      |
| TPS 0.3 to 0.6 m, %| 62.8  | 57.4 | 60.0 | 64.9 | 71.8 | 6 (5 to 7)      |
| Ksat, mm h$^{-1}$  | 8.6   | 4.3  | 6.2  | 11.4 | 13.8 | 35 (28 to 36)   |
| N, kg              | 136.9 | 68.5 | 105.0| 154.3| 252  | 29 (24 to 33)   |
| P$_2$O$_5$, kg     | 79.7  | 30.0 | 52.5 | 102  | 135  | 37 (24 to 40)   |
| K$_2$O, kg         | 46.0  | 15.0 | 30.0 | 52.5 | 180  | 70 (41 to 83)   |
| WS grain yield, ton| 6.9   | 5.0  | 6.0  | 7.6  | 9.2  | 16 (13 to 18)   |
| DS grain yield, ton| 2.9   | 1.5  | 2.4  | 4    | 4.2  | 28 (27 to 28)   |
| Crop Index         | 2.7   | 2.0  | 2.0  | 3    | 3    | 17 (15 to 19)   |

*CV, the coefficient of variation calculated from the average value of 30 farmers at the survey location. The values shown are the mean CV of tidal swamp rice and the ranges in the two types (in brackets).

Sand content was inversely related with silt and clay (p <0.001) and BD 0 to 0.3 m (p <0.01) and BD 0.3 to 0.6 m (p <0.05) across the 30 farmers field (table 5). High sand content can affect the water holding capacity which results in N loss and production [36]. Planting with a planting index of 2 to 3 with high clay content can be done as long as water is available throughout the season [41]. Furthermore, Bulk density 0
to 0.3 m was directly related (p < 0.001) to BD 0.3 to 0.6 m while inversely related to total pore space (TPS) 0 to 0.3 m TPS 0.3 to 0.6 m. More TPS corresponded to low availability of P₂O₅ and grain yield in WS, as indicated by high infiltration.

Application of P₂O₅ was directly related to grain yield in WS 2018/2019 (p < 0.001) and DS 2019 (p < 0.05). The range of P₂O₅ applications between 30 to 135 kg ha⁻¹ with an average of 79.7 kg ha⁻¹ is already in the high category with 100% return of straw to the field using a combine harvester. Masganti et al [25] stated that recommendation for rice fertilization in tidal swamp rice is 60 kg ha⁻¹ plus 2 t ha⁻¹ organic fertilizer. According to the soil analysis data (table 1), the P available at the research location is in the very high category.

Table 4. shows the status of pests and diseases, climate, and grain yield for the 2011/2012 to 2020 period in South Sumatra. The highest total area attacked per season was caused by Rattus argentiventer, Cnaphalocrosis medinalis, Pyricularia grisea, and Leptocorisa oratorius, each with an area of 137.8 ha; 139.6 ha; 144.6 ha; and 86.7 ha with CV 97; 99; 121; and 81 for 18 growing seasons with high CV variations between type B and type C. This affects the mean grain yield in the range 1.5 to 7.3 with CV 11 to 26. Climatic factors such as total rainfall, mean temperature, and humidity have low variations with CV 21; 1; and 4 as well as between land types B and C.

| Parameter                      | Mean | Min | 25%  | 75%  | Max  | CV among field |
|--------------------------------|------|-----|------|------|------|----------------|
| Gryllotalpa brachyptera        | 33.5 | 3.0 | 7.0  | 159.8| 385.0| 166 (53 to 199)|
| Pomacea canaliculata           | 46.1 | 7.5 | 21.8 | 160.8| 224.5| 82 (62 to 120) |
| Rattus argentiventer           | 137.8| 11.0| 32.8 | 187.8| 456.0| 97 (90 to 110) |
| Cnaphalocrosis Medinalis       | 139.6| 9.0 | 60.3 | 317.4| 735.0| 99 (44 to 91)  |
| Pyricularia grisea             | 144.6| 15.5| 29.0 | 192.5| 682.0| 121 (51 to 109)|
| Leptocorisa oratorius          | 86.7 | 21.5| 47.8 | 182.3| 324.0| 81 (80 to 86)  |
| Helminthosporium Oryzae        | 12.4 | 3.0 | 7.0  | 58.8 | 70.0 | 97 (31 to 104) |
| Bacterial leaf blight          | 28.3 | 2.0 | 6.1  | 95.0 | 170.0| 129 (108 to 114)|
| Mythimna separat a              | 13.6 | 19.0| 19.5 | 124.0| 146.0| 97 (72 to 106) |
| Nilaparvata lugens             | 34.8 | 2.5 | 3.5  | 127.5| 369.0| 147 (63 to 117)|
| Scirpophaga incertulas         | 26.7 | 16.0| 17.3 | 212.0| 212.0| 128 (98 to 141)|
| Total rainfall                 | 999.9| 568.2| 824.1| 1137.8| 1388.2| 21 (17 to 27) |
| Mean temperature               | 27.6 | 26.9| 27.5 | 27.8 | 28.0 | 1 (1 to 2)     |
| Humidity                       | 85.0 | 79.7| 83.2 | 86.3 | 90.3 | 4 (3 to 4)     |
| Grain yield                    | 4.4  | 1.5 | 2.1  | 6.8  | 7.3  | 51 (11 to 26)  |

† CV, the coefficient of variation calculated from the average value of 30 farmers at the survey location. The values shown are the mean CV of tidal swamp rice and the ranges in the two types (in brackets).

The mean total area offensive per season of Rattus argentiventer was directly related to the extent of attack by Leptocorisa oratorius and Helminthosporium Oryzae (P < 0.001) also Bacterial leaf blight, Scirpophaga incertulas, and Humidity (P < 0.01) across the 18s seasons. Leptocorisa oratorius was directly related to Helminthosporium Oryzae (P < 0.001), Bacterial leaf blight, and Scirpophaga incertulas (P < 0.01) while it was inversely related to grain yield (P < 0.05). The increased attack area of Helminthosporium Oryzae was due to the increasing humidity (P < 0.05) and it was directly related to Bacterial leaf blight and
Scirpophaga incertulas (P <0.001). Mean temperature was inversely related to medial Cnaphalocrosis (P <0.001), Gryllotalpa brachyptera and total rainfall (P <0.05). The high variation in mean grain yield of 1.5 to 7.3 t ha⁻¹ was related to season (P <0.001). Rice planting is not synchronous due to limited labor and most farmers use the salibu/fallow method in the second season. Based on Pujiastuti et al [43] the highest rat attack in DS I started from initial growth to harvest by cutting 5 rice stalks and eating one plant.

3.4. Rice farming analysis
According to the farming analysis in table 1, it shows that labor is the highest contributor (63%) to rice production input in South Sumatra. Generally, the workforce comes from the farming families themselves, especially for fertilizer application, weeding, and pest and disease control. The second component is fertilizer at 18.8%. According to [44] the labor costs are the main input (63%) followed by fertilizer (20%), seed (7%), pesticide (6%), and water irrigation (4%). The limited workforce in tidal swamp rice [37] provides an opportunity for the government to introduce agricultural mechanization in 2015 to support an increase in the cropping index (IP) and a program to save swamps, prosper farmers (Serasi) in South Sumatra. Based on Umar and Alihamsyah [45] the contribution of family labor is only 70% and the rest uses agricultural mechanization to overcome labor shortages. Furthermore, WS rice production was 58% higher than that of DS with components of farmer revenue of 29.14 million and 13.30 million, respectively. This is reinforced by the higher income of farmers in WS compared to DS with Revenue Cost Ratio (R/C) of 2.5 and 1.2, respectively, which means that every rupiah spent by farmers gets a return of 2.5 and 1.2-rupiah.
### Table 5. Pearson correlation coefficient between soil physical properties and farmer fertilizer application, production, and crop index (CI) on WS 2018/2019 and DS 2019 for 30 respondent farmers in South Sumatra.

| Parameter                        | Silta) | Siltb) | Claybe) | BDCd) | BDe) | TPSf) | TPSg) | Ksath) | P2O5i) | K2Oj) | WS grain yield | DS grain yield | CI |
|----------------------------------|--------|--------|---------|--------|------|-------|-------|--------|--------|-------|----------------|----------------|----|
| Sand, %                          | -0.68*** | -0.88*** | -0.51** | -0.38* | 0.46** | 0.33  | 0.10  | -0.28  | -0.25  | -0.33 | -0.04          | -0.27          |    |
| Silt, %                          | 0.24   | 0.46*  | 0.22    | -0.34  | -0.11 | 0.23  | 0.23  | -0.13  | 0.15   | 0.07  | 0.07           | 0.06           |    |
| Clay, %                          | 0.37   | 0.35   | -0.38*  | -0.37** | -0.28 | 0.28  | 0.46** | 0.24   | 0.40*  | 0.40* | 0.20           | 0.32           |    |
| BD 0-0.3 m, g cm⁻³               | 0.65*** | -0.77*** | -0.63** | -0.27  | 0.22  | -0.07 | 0.34  | 0.10   | 0.39*  | 0.10  | 0.39*          | 0.39*          |    |
| BD 0.3-0.6 m, g cm⁻³             | -0.35  | 0.10   | 0.14    | 0.10   | 0.09  | -0.08 | 0.24  |        |        |      |                |                |    |
| TPS 0.0-0.3 m, %                 | 0.83***| 0.52** | -0.43*  | 0.39*  | -0.41* | -0.13 | -0.33 |       |       |      |                |                |    |
| TPS 0.3-0.6 m, %                 | -0.35  | 0.37   | -0.33  | 0.13   | 0.29  |       |       |       |       |      |                |                |    |
| Ksat, cm jam⁻¹                   | -0.38* | 0.33   | -0.37*  | -0.01  | 0.23  |       |       |       |       |      |                |                |    |
| N, kg ha⁻¹                       | -0.19  | 0.35   | -0.12  | -0.37* | -0.14 |       |       |       |       |      |                |                |    |
| P2O5, kg ha⁻¹                    | -0.26  | 0.70***| 0.43*  | 0.34   |       |       |       |       |       |      |                |                |    |
| WS grain yield, t ha⁻¹           | 0.96***| 0.40*  |        |        |       |       |       |       |       |      |                |                |    |

* *, **, and *** denote significance at the probability level of 0.05, 0.01, and 0.001, respectively.
a, b, c, e top 0.3 m soil layer.
d, f soil layer 0.3-0.6 m.

### Table 6. Pearson correlation coefficient between pests and diseases with climate and grain yield for 18 seasons (WS 2011/2012 to DS 2020) in South Sumatra.

| Parameter                           | Caphalocrosis Medinalis | Pyricularia grisea | Leptocorisa oratorius | Helminthisporium Oryzae | Bacterial leaf blight | Mythimna separata | Scirpophaga incertulas | Mean temperature (°C) | Humidity (%) | Grain yield (t ha⁻¹) |
|-------------------------------------|-------------------------|-------------------|-----------------------|-------------------------|----------------------|-------------------|------------------------|-----------------------|--------------|---------------------|
| Season                              | 0.31                    | 0.59*             | 0.03                  | 0.82**                  | 0.05                 | -0.05             | 0.05                   | -0.04                 | 0.01          | 0.96***             |
| Gryllotalpa brachyptera, ha⁻¹       | 0.43                    | 0.59*             | -0.16                 | 0.82**                  | 0.23                 | -0.14             | -0.31                  | -0.53                 | 0.03          | 0.25                |
| Rattus argentiventer                | 0.51*                   | -0.01             | 0.86***               | 0.63*                   | 0.05                 | 0.69*             | 0.05                   | 0.61                  | 0.03          | 0.57*               |
| Caphalocrosis Medinalis             | 0.27                    | 0.21              | 0.31                  | 0.10                    | 0.61**               | -0.05             | 0.04                   | 0.60*                 | -0.31         | 0.27                |
| Leptocorisa oratorius               | 0.80**                  | 0.58**            | 0.12                  | 0.69**                  | 0.05                 | 0.43              | 0.50*                  | 0.60*                 | -0.15         | -0.31               |
| Helminthisporium Oryzae             | 0.82**                  | 0.14              | 0.86***               | -0.08                   | 0.50*                | -0.31             |                        |                       |              |                    |
| Bacterial leaf blight               | -0.17                   | 0.89***           | -0.04                 | 0.60*                   | 0.53*                | 0.31              | -0.10                  |                       |              |                    |

* *, **, and *** denote significance at the probability level of 0.05, 0.01, and 0.001, respectively.
Pest, disease and climate data for 18 seasons since WS 2019/2020-DS 2020 comes from BPTP-H and BMKG South Sumatra.
Table 7. Analysis of tidal swamp rice farming in Muara Telang Sub-district, Banyuasin Regency, South Sumatra.

| Input                        | Type B | Type C | Percentage |
|------------------------------|--------|--------|------------|
|                              | WS     | DS     | WS         | DS         |           |
| Mean area of cultivated land | 1.3    | 1.4    | 1.3        | 1.4        |
| Productivity, t ha⁻¹         | 7.4    | 3.0    | 6.8        | 2.9        |

| Variable Cost per ha (IDR 000) *) |
|-----------------------------------|
| Labor                             | 7,687  | 8,022  | 6,343      | 6,546      |
| Seed                              | 827    | 775    | 529        | 504        |
| Fertilizer                        | 2,120  | 1,653  | 2,084      | 1,956      |
| Pesticide                         | 2,098  | 1,570  | 1,601      | 1,368      |
| Property tax                      | 8      | 8      | 8          | 8          |
| Total cost                        | 12,741 | 12,028 | 10,566     | 10,383     |
| Receipt                           | 30,243 | 13,410 | 28,044     | 13,185     |
| Total cost                        | 12,741 | 12,028 | 10,566     | 10,383     |
| R/C                               | 2.37   | 1.11   | 2.65       | 1.27       |

Note: *) The values used are rounded values.

4. Conclusions

The success of the agricultural land expansion program using tidal swamp rice must be balanced with an intensification program. Agricultural mechanization assistance and other agricultural inputs which have been intensely carried out in the last five years have had a positive impact in increasing soil fertility. Furthermore, the relationship of soil physical properties such as increased TPS corresponded to low availability of P₂O₅ and grain yield in WS, as indicating by high infiltration is inversely proportional to BD and CI. On the other hand, Rattus argentiventer is the highest attack in every season which is directly proportional to temperature, pest and disease attacks such as Leptocorisa oratorius, Helminthosporium Oryzae, and Bacterial leaf blight, but inversely proportional to humidity. Profits in WS are 58% higher than DS (R/C ratio 2.5 and 1.2) where the highest input component is 63% of the labor cost. Agricultural mechanization, simultaneous planting, water management, and site-specific fertilization can increase rice productivity, cropping index, and fertilizer efficiency in tidal swamp rice.

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