The use of green super rice varieties and harvest waste in sustainable rice farming in tidal lands

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Abstract. The practice of increasing rice productivity in tidal swamp lands is guided by synergistic cultivation through integrated crop management (ICM). The objective of the study was to improve technology through the use of crop residue and increase rice productivity in tidal land. The superior varieties from Green Super Rice (GSR) group used was Inpari 42 and 43, combined with straw left in the land, site-specific fertilization, and dolomite application. The study was conducted from April 2017 to September 2018 in the tidal land of Belanti Siam Village. The method of participatory on farm and farmers activities involves 10 farmers on an area of 10 ha. The results proved that the application of 5 t ha⁻¹ of straw waste remains in the land after harvesting, and the addition of 0.5 to 1 t ha⁻¹, dolomite, were able to increase soil pH from 4.0 to 4.2. Application of the straw waste, rice productivity increased by 32% (4.8 t ha⁻¹) after the first application and further 21% (5.1 t ha⁻¹) after the second application for the Inpari 42 variety. The productivity levels of Inpari 43 variety increased 112% (4.8 t ha⁻¹) and 16% (5.6 t ha⁻¹) after the first and the second applications, respectively.

1. Introduction
Swamp land in Kalimantan covered 10.62 million ha, both on tidal swamp land and swampy land. These lands have the potential and have been used for food crops, especially rice. Various obstacles faced in swamps include standing water, high acidity and pyrite poisoning, nutrient deficiency and imperfect water drainage. As a result, rice farming conditions are not optimal, with superior rice productivity only 3.2 to 4.0 t ha⁻¹ and local rice 1.5 to 2.0 t ha⁻¹ [1]. Various innovations for improvement have been produced, such as the use of ameliorants, one-way water system improvements, and ways to manage land. Likewise, with the assembly of specific swampland varieties, such as the Kapuas, Dendang, Inpara 3, Martapura varieties, etc., however, some of these superior varieties only excel in certain properties, but cannot withstand extreme environments. Apart from that, the texture and taste of rice is generally not preferred by the local community, so that many farmers who have recognized and planted superior varieties have returned to planting local rice.

Green Super Rice (GSR) is an environmentally friendly rice variety, which contains various superior characteristics of rice varieties from various locations adapted to environmental conditions both biotic and abiotic. Thus, the resulting GSR varieties have various advantages, such as efficient use of water, fertilizers, herbicides, resistance to pests and diseases and high production [2]. This is in line with the farming patterns of local communities in swamplands, who generally plant local rice which is need small amount or even without fertilizer. The presence of GSR varieties is expected to replace the position...
Local rice and be acceptable to farmers, because GSR varieties require lower input than general superior varieties, from efficient and environmentally friendly. Two varieties of rice from the GSR group that have been released by the Minister of Agriculture are Inpari 42 Agritan GSR with Ministerial Decree No. 372/Kpts/TP.010/6/2016 and Inpari 43 Agritan GSR with Ministerial Decree No. 373/Kpts/TP.010/6/2016.

The use of environmentally friendly superior varieties Inpari 42 and Inpari 43 combined with other components in an effort to increase rice productivity is part of the principle of implementing a sustainable environmentally friendly agricultural system [3, 4, 5]. Several technology components that are capable of providing high crop yields, low greenhouse gas emissions, and low contaminants, including the use of ripe organic matter (low C/N ratio) are soil ameliorants or ameliorants [6, 7]. The soil ameliorant can be in the form of dolomite lime, husk charcoal, straw fermentation, etc. [8]. Currently, rice straw has not been widely used as raw material or substitute material in the process of producing goods. Generally, rice straw produced from harvesting is only burned in the rice fields with the aim of being able to improve the physical and chemical properties of the soil and to reduce the cost of transportation or transportation out of the rice field when it piles up.

The harvest operations using Combine Harvester, left a lot of straw. It was scattered all over the rice fields. The use of straw as additional to animal feed can also produce organic fertilizers through the fermentation process. In this study, the remaining straw in the land after harvesting was left improper, then some microbial from commercial decomposer was applied to accelerate decomposition. After entering the planting period or about one month after harvesting, the land was prepared for the next planting.

The purpose of this study is to obtain information on tidal land improvement technology through providing the remaining straw left in the land and increasing the productivity of environmentally friendly rice, especially through the application of a technology package consisting of rice harvest waste in the form of straw combined with the use of environmentally friendly varieties and balanced inorganic fertilizers as well as dolomite.

2. Materials and methods

2.1. Time and place
The study was carried out in tidal swamp land with flooding type B, Belanti Siam village, Pandih Batu sub-district, Pulang Pisau district, from March 2017 to September 2018. The farmers involved were 10 members of the Rukun Sentosa farmer group, namely five farmers who planted the Inpari 42 variety and five people who planted the Inpari 43 variety, with an area of one hectare each being used as a sample, so a total of 10 ha.

The cultivation technology carried out was an application of the utilization of rice straw waste and GSR varieties followed by perfect soil processing. A total of 500 kg ha⁻¹ of dolomite lime was applied after the soil tillage was completed or a week before planting. Inorganic fertilizers were equally given the same for each field with a dose of 150 kg urea and 250 kg NPK per ha. This dose refers to the recommendations based on the result of local soil analysis.

2.2. Straw waste calculation and data collection
All straw left in the field was accounted for as the hay dose applied to the field, as part of the organic matter component. The amount or dose of straw is calculated based on the ratio between the weight of the previously harvested grain and the remaining straw left on the land (grain straw ratio), which is 2:3 [9]. The type of straw calculated on the harvested land is the same as the grain harvested, namely Inpari 42 and Inpari 43. Furthermore, all the straw in the land for 1 to 1.5 month until the next tillage.

Data collection from each farmer was carried out by calculating the productivity of rice and remaining straw waste from each farmer, namely five farmers for the Inpari 42 variety and five farmers for the Inpari 43 variety. All data were quantitatively calculated and tabulated in MS Excel form.
2.3. Agronomic data processing and analysis
The collected agronomic data was collected both growth and production data. For growing data such as plant height (PH) and number of tiller (NoT) were observed on 30 days after planting (DAP), 45 and 60 DAP. The collection of production data consisting of the number of productive tillers, panicle length, number of filled grains per panicle, number of empty grains per panicle, weight of 1,000 grains and yield were observed at harvest time. All observations were made by referring to the standards issued by IRRI.

The data was collected by diagonally sampling from each farmer’s land. Three plants were taken at each point, so that 15 sample plants were collected from each farmer’s land with area 1.0 ha. The amount of straw produced from the previous planting for each farmer and variety. All data was processed on average and displayed in tabular form and analyzed quantitatively. All yields are calculated in the form of straw produced from the previous planting for each farmer and variety.

3. Results and discussion
In the first cropping of GSR environmentally friendly rice varieties, which were planted in the first planting season, the observed data on yield components were recorded. The data then was used to calculate the amount of straw waste that will be applied, which is calculated based on the level of productivity. In the first planting season, the period mentioned above shows that the average productivity of Inpari 42 was 3.16 t ha\(^{-1}\) and Inpari 43 was 3.30 t ha\(^{-1}\). Referring to Makarim et al. [9], the amount of straw left in the land is obtained at a ratio of 2:3 of the productivity obtained. Thus, the remaining straw on the land calculated from each productivity level ranges from 4.5 to 5.4 t ha\(^{-1}\) (table 1). The availability of straw in the land was used as part of the technology components used in assembling technology packages that are applied to subsequent crops, and so on (table 2).

| No | Farmer Names | Varieties  | Land Area (ha) | Productivity (t ha\(^{-1}\)) gkg* | Estimated rice straw (t ha\(^{-1}\)) |
|----|--------------|-----------|----------------|-----------------------------------|----------------------------------|
| 1  | Agus         | Inpari 42 | 1              | 3.1                               | 4.7                              |
| 2  | Budi         | Inpari 42 | 1              | 3.3                               | 5.0                              |
| 3  | Barni        | Inpari 42 | 1              | 3.0                               | 4.5                              |
| 4  | Gimin S      | Inpari 42 | 1              | 3.2                               | 4.8                              |
| 5  | Dasuki       | Inpari 42 | 1              | 3.2                               | 4.8                              |
| 6  | Ribut        | Inpari 43 | 1              | 3.4                               | 5.1                              |
| 7  | Moyo         | Inpari 43 | 1              | 3.6                               | 5.4                              |
| 8  | Kiki         | Inpari 43 | 1              | 3.2                               | 4.8                              |
| 9  | Tofiq        | Inpari 43 | 1              | 3.2                               | 4.8                              |
| 10 | Darmanto     | Inpari 43 | 1              | 3.1                               | 4.7                              |

* gkg = dry unhulled rice.

| Technology Components | Group A       | Group B       |
|-----------------------|---------------|---------------|
| Cultivation           | Perfect cultivation | Perfect cultivation |
| Varieties GSR         | Inpari 42     | Inpari 43     |
| Seed                  | 25 kg ha\(^{-1}\) | 25 kg ha\(^{-1}\) |
| Dolomite              | 500 kg ha\(^{-1}\) | 500 kg ha\(^{-1}\) |
| Straw per season      | 4.5 – 5.0 t ha\(^{-1}\) | 4.7 – 5.4 t ha\(^{-1}\) |
| Urea                  | 150 kg ha\(^{-1}\) | 150 kg ha\(^{-1}\) |
| NPK                   | 250 kg ha\(^{-1}\) | 250 kg ha\(^{-1}\) |
| Plant method          | Jarwo 2:1     | Jarwo 2:1     |
3.1. Characteristics of growth and rice production in the GSR group

The application of technology packages carried out in tidal fields refers to the efforts reducing the application of inorganic fertilizers by utilizing harvest waste in the form of straw that is left in the land and used immediately after harvesting or subsequent planting. From the applications carried out by farmers in the field, observations on the character of plant growth showed that almost all plants managed by 10 farmers grew well and vigorously. The results of observations on growth characters showed that the average plant height and number of tillers of Inpari 43 variety were higher than Inpari 42 at the age of 30 and 45 DAP, however, at the age of 60 DAP the plant height and the number of tillers of Inpari 42 variety were higher than Inpari 43 (table 3).

Table 3. Growth characters of cultivated rice varieties during the rainy season from October 2017 to March 2018.

| Varieties | Names   | 30 DAP | 45 DAP | 60 DAP |
|-----------|---------|--------|--------|--------|
|           |         | PH     | NoT    | PH     | NoT    | PH     | NoT    |
| Inpari 42 | Agus    | 44.55  | 11.23  | 55.65  | 12.41  | 84.66  | 16.55  |
|           | Budi    | 45.12  | 11.55  | 56.16  | 12.43  | 85.21  | 15.74  |
|           | Barni   | 43.87  | 11.12  | 55.23  | 12.32  | 85.66  | 16.33  |
|           | Gimin S | 44.23  | 11.31  | 55.44  | 12.22  | 84.32  | 15.58  |
|           | Dasuki  | 43.45  | 10.93  | 54.68  | 12.14  | 84.36  | 16.65  |
| Inpari 43 | Ribut   | 46.21  | 13.81  | 57.21  | 14.02  | 79.87  | 14.33  |
|           | Moyo    | 45.76  | 12.57  | 56.66  | 13.92  | 78.67  | 14.12  |
|           | Kiki    | 47.11  | 13.21  | 57.24  | 14.13  | 79.49  | 14.03  |
|           | Tofiq   | 46.32  | 13.12  | 55.76  | 14.32  | 77.54  | 14.53  |
|           | Darmanto| 46.43  | 13.34  | 57.43  | 14.11  | 78.53  | 14.13  |

Notes: DAP = day after planting; PH = plant height; NoT = Number of tillers.

The observations during the period from harvesting to the next planting showed that it takes about three months from harvesting or from the time when the straw waste is obtained until the next planting in which the straw waste can be utilized. The cropping time for the April to September period (planting season I) was carried out at the 4th week of July to the first week of September, or about 1.5 months, and the next planting was started at the first and second weeks of October. During this period, the straw still remained in the field to allow the process of forming organic matter occur and naturally decomposing in the soil. This is in line with Nuraini [10] and Nyoman et al. [11] who states that the process of making or forming organic fertilizers was naturally takes about three months, so the measurement of the effect of the remaining straw waste in the field is appropriate. The process of plant development at the vegetative period between the age of the plant 30 and 45 days after planting, showed that the variety of Inpari 43 was better than Inpari 42, and conversely the Inpari 42 variety was able to produce plant height and a higher number of tillers at the age of 60 days after planting. This condition was influenced by environment, especially the application of straw and other waste materials, considering that plant height was an indicator of growth and a parameter that was often used as a measure of environmental influence [12].

Several production characters were observed at harvest. In the planting period of October 2017 to March 2018, showed that most of the plants planted by the implementing farmers had a number of productive tillers that were not significantly different, both Inpari 42 and Inpari 43 varieties. This condition can be assumed because of the nutrient content in the soil which provided to plants that meet the needs of the plant to produce the number of tillers from the plants planted by farmers. Furthermore, the straw waste that has been combined with fertilizer and lime has not affected the development of the number of productive tillers. Punomo et al. [13] explained that there are several plant properties that need to be considered in the use of nutrients by plants and the characteristics of roots, namely the ability to produce productive tillers. Observation of panicle length showed that Inpari 43 variety was able to produce panicles up to 24.78 cm in length, not significantly different with the panicle length produced.
by all farmers. The length of the panicle is related to the amount of grain produced by the plant, where the longer the panicle, the more grain it will be produced. This is related to the growth and development of panicle length which is influenced by genetic and environmental factors, such as those produced in Pak Ribut's land and Pak Topic's land (table 4).

### Table 4. Production data of rice varieties planted during the rainy season October 2017 to March 2018 period.

| Varieties | Name  | NPT  | PL   | TG   | FG   | EG   | W 1000 | Yield  |
|-----------|-------|------|------|------|------|------|--------|--------|
| Inpari 42 | Agus  | 14.33| 21.89| 201.91| 147.10| 54.81| 24.71  | 4.38   |
|           | Budi  | 19.44| 23.00| 177.99| 134.00| 43.91| 24.80  | 4.11   |
|           | Barni | 13.55| 21.55| 197.66| 151.49| 46.18| 24.47  | 3.61   |
|           | Gimin | 18.00| 22.62| 220.15| 145.35| 60.80| 24.81  | 4.72   |
|           | Dasuki| 20.11| 21.89| 176.40| 119.35| 57.04| 24.53  | 4.33   |
| Inpari 43 | Ribut | 15.66| 24.00| 282.84| 196.66| 86.19| 25.20  | 5.11   |
|           | Moyo  | 16.78| 22.34| 210.16| 142.12| 68.04| 24.55  | 5.22   |
|           | Kiki  | 14.44| 23.11| 231.53| 156.91| 74.62| 25.49  | 4.56   |
|           | Tofiq | 14.44| 24.78| 248.21| 172.60| 75.61| 24.36  | 4.22   |
|           | Darma | 18.00| 22.89| 197.15| 133.35| 63.80| 24.83  | 4.72   |

Notes: NPT = the number of productive tillers; PL = panicle length, TG = Total grain; FG = the number of filled grains per panicle; EG = the number of empty grains per panicle; W 1000 = weight of 1,000 grains; and yield.

For the number of Inpari 43 husk rice planted in the land of the Ribut farmers, it produced 282.84 grains, but it was not significantly different from those produced in the Kiki and Tofik fields. However, it was significantly different from other farmers, including the Inpari 42 variety. Farmers were not significantly different for both Inpari 42 and 43 varieties, but based on their production capacity, the average productivity level of Inpari 43 was higher than Inpari 42 variety, namely 4.77 t ha$^{-1}$ for Inpari 43 and Inpari 42 as much as 4.23 t ha$^{-1}$ milled dry unhulled rice (gkg) (table 4).

#### 3.2. Grain productivity and yield per season

Based on the observation on the yield of grain each season and the amount of straw left on the land, there was an increase in both the productivity of the rice itself and the straw. The increased productivity, the more straw that is produced and applied naturally in tidal fields. Table 5 shows that the average of straw waste produced by Inpari 42 and Inpari 43 varieties was 4.8 t and 5.0 t of wet straw, and when combined with other fertilizers with the same amount each season able to increase productivity by 32% compared to planting season I with an average yield of 4.2 t ha$^{-1}$ gkg, and an increase of 21% in the third season with a province of 5.1 t ha$^{-1}$. As for the Inpari 43 variety, it was able to produce respectively 4.8 t ha$^{-1}$ in season 2 and 5.8 t ha$^{-1}$ in season 3.

The increase in GSR rice productivity for both Inpari 42 and Inpari 43 proved the ability of organic matter to improve soil fertility. Although this ability depends on the source of the organic material used [14]. The results of the analysis of variance at MT II showed that the productivity of GSR varieties planted in tidal flats of type B was influenced by rice straw waste left in the field, fertilization and interactions with others. Likewise, the results in season II and III were continued to increase. The straw waste that can contribute to P also plays a role in increasing the productivity of rice cultivated in tidal land. This condition is in line with Masganti [15] which stated that the availability of P in the soil in tidal land is low, so that giving P to P-deficient soils will increase rice productivity. In addition to P supply from TSP fertilizer, P also comes directly from rice straw compost [16]. Another contribution from rice straw waste which indirectly affects P availability is the decreased solubility of Al and Fe which usually binds P, so that availability of P is better.
Table 5. Productivities of rice and straw residual in the planting period April 2017 to September 2018.

| Varieties | Farmers | April-Sept 2017 | Oct-march 2017/2018 | April-Sept 2018 |
|-----------|---------|-----------------|---------------------|-----------------|
|           |         | Yield (t ha⁻¹)  | Straw (t ha⁻¹)     | Yield (t ha⁻¹)  | Straw (t ha⁻¹) |
| Inpari 42 | Agus   | 3.1             | 4.7                 | 4.4             | 6.6             | 5.3             | 7.9             |
|           | Budi   | 3.3             | 5.0                 | 4.1             | 6.1             | 4.9             | 7.4             |
|           | Barni  | 3.0             | 4.5                 | 3.6             | 5.4             | 4.3             | 6.5             |
|           | Gimin S| 3.2             | 4.8                 | 4.7             | 7.1             | 5.7             | 8.5             |
|           | Dasuki | 3.2             | 4.8                 | 4.3             | 6.7             | 5.2             | 7.8             |
| Inpari 43 | Ribut  | 3.4             | 5.1                 | 5.1             | 7.7             | 5.9             | 8.9             |
|           | Moyo   | 3.6             | 5.4                 | 5.2             | 7.8             | 5.7             | 8.6             |
|           | Kiki   | 3.2             | 4.8                 | 4.6             | 6.8             | 5.5             | 8.2             |
|           | Tofiq  | 3.2             | 4.8                 | 4.2             | 6.3             | 5.1             | 7.6             |
|           | Darmanto| 3.1            | 4.7                 | 4.7             | 7.1             | 5.7             | 8.5             |

4. Conclusions

Tidal swamp land which has various constraints such as high acidity and nutrient deficiency can be overcome, among others, using rice straw waste that is left in the land, which can be considered as a soil amendment agent in tidal fields as well as organic fertilizer for plants. In terms of increasing the productivity of superior rice, the yield of rice varieties from the green super rice group proved to be very responsive to straw utilization in tidal fields. In the third season after the application of the straw waste, there was an increase in rice productivity by 32% after the first application (4.8 t ha⁻¹) and a further 21% increase (5.1 t ha⁻¹) after the 2nd application for the Inpari 42. The amount of productivity levels for Inpari 43 variety showed an increase of 112% (4.8 t ha⁻¹) after the first application and further increased to 16% (5.6 t ha⁻¹) after the second application.

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