Strategies for selecting rice varieties in anticipation of the climate change impacts in swampland

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Abstract. The efforts to increase rice production in swampland are faced with various obstacles, including extreme climate change (drought and flooding). To overcome the drought and flooding conditions is by planting suitable rice varieties for its conditions. During el nino, very early maturity varieties could be planted such as Inpari 12, 13, 18, 19, and 20 (99 to 104 days old). Somewhat drought tolerant varieties, such as Inpari 38, 39, and 40. In la nina conditions could be planted Inpara 3, 4, and 5 because these varieties were moderately submergence tolerant. Inpara 3 was tolerant to submergence for 6 days, while Inpara 4 and 5 were tolerant for 14 days in the vegetative phase. Furthermore, the Inpari 29 and 30 Ciherang Sub-1 could also submergence tolerant for 14 and 15 days, respectively. By planting early maturity and submergence tolerant varieties, it is hoped that rice production in swampland can be maintained under climate change. This paper is a review and the purpose of this paper is to anticipate the effects of extreme climate change (el-nino and la-nina) through using rice varieties in swamplands and strategy for selecting the varieties so that they can produce under extreme climate changes.

1. Introduction
Swamplands as one of the suboptimal lands, now and in the future are increasingly playing an important role in efforts to increase rice production. This is related to the shrinking of productive land from year to year, especially in Java for various development activities such as settlements, roads, and various other business activities. The area of swamps in Indonesia reaches 34.93 million ha, around 19.99 million ha of which are potential land for agriculture. Of this land area, there are 8.35 million ha of tidal land, 11.64 million ha of swampy land, and 14.92 million ha of peatland [1].

The potential for swamps for rice fields is quite large. Rice cultivation in swamps has been known to the farming community for a long time. Rice is a strategic commodity that is cultivated in swamps. Rice cultivation in tidal swampland is generally still traditional, once a year using a transplanting system, local varieties, limited fertilizers so that the production is low between 1.5-2.0 t ha−1 [2], [3], [4].

Various researches and developments continue to be carried out to increase rice production in swamps. The results showed that superior rice productivity in acid sulfate land with good technology could reach 4.80-6.61 t ha−1 [5], [6]. One of the components of rice cultivation technology is the use of high yielding varieties. The use of the right high yielding varieties will spur an increase in rice production. However, not all high yielding varieties are suitable for swamps, due to several limiting factors, including land agrophysics. Accuracy in selecting new high yielding varieties is an important step in increasing production so that there is no wide yield gap between factual and potential yields.
Apart from yield factors, several other factors, such as farmers’ and consumers’ preferences and acceptability, also need to be considered.

This paper aims to provide information on the importance of strategy selecting suitable and acceptable rice varieties in swamplands so that production can be increased. The determinants in the selection of superior rice varieties to be developed in swamplands are described in this paper based on a review of research results and thoughts as well as knowledge and field experience.

2. Specifications of land typology and type of overflow in swamplands

The selection of rice varieties in swamplands is specific because swamplands have distinctive characteristics. Swampland consists of tidal and swampy land. Based on the type of soil, tidal land is divided into four land typologies, namely potential land, acid sulfate, saline, and peat. Land physical problems, especially in acid sulphate soils (high Fe and Al, low pH), saline (salinity), and peat (lack of Cu and Zn micro elements) [7].

Potential land is land whose soil includes potential acid sulphate soil with a pyrite content of 2% at a depth of > 50 cm from the soil surface, while acid sulphate soil has a pyrite layer > 2% at a depth of <50 cm. The acid sulfate fields are divided into potential acid sulfate fields (pyrite has not been oxidized) and actual (pyrite has been oxidized). Peatland is land with 12-18% organic carbon content. Based on the thickness of the peat, peatlands are divided into peatlands (peat layer thickness 20-50 cm), shallow peat (50-100 cm), medium peat (100-200 cm), deep peat (200-300 cm), and very deep peat, deep (> 300 cm). Saline land is land that is affected by or intrusion of salt water with Na content > 8% in soil solution for > 3 months in a year [8].

Based on the type of water overflow, tidal areas are divided into four types, namely types A, B, C, and D (Figure 1). Type A land always overflows with high tide and is double tidal and drained daily; type B overflowed with large tides and drained daily; type C is not tidal and permanently drained; and type D does not have a tidal effect and is limited in drainage. The difference in water level at single tide between the rainy and dry seasons on land type A reaches 30 cm and in type B 40 cm; on land type B 70 cm. In type C, the water level in the rainy season reaches 65 cm, but in the dry season the water level is > 70 cm below the soil surface. The difference in water level between tide and low tide in the secondary channel ranges from 1.5-2.5 m [7], [9], [10].

Reclamation activities or the creation of water systems can change the type of overflow in swamp areas. The reclamation channel causes the tide to reach further into the interior so that the area that was originally type C can become type B. If drainage occurs due to the construction of a water system network, the area that was originally type B can become type C because the groundwater level is getting deeper. Almost all areas of type B after reclamation change to type C, such as in the Pulau Petak area, South Kalimantan [7].

The freshwater of swampland is divided according to height and length of inundation, namely shallow, intermediate, and deep. Shallow freshwater of swampland with inundation height <50 cm for <3 months, intermediate inundation area 50-100 cm for 3 - 6 months; flooding in > 100 cm for > 6 months (Figure 2).
3. Climate stress on swampland rice productivity

The extreme climate can create stress for rice agronomically. Drought will change the physiological mechanism in the form of inhibition of plant growth through disruption of roots and canopy of plants due to dehydration. Dehydration causes a decrease in turgor pressure by closing stomata so that diffusion of carbon dioxide (CO₂) gas is inhibited and photosynthesis is disrupted, carbohydrate formation decreases so that plants grow stunted. Flooding had an indirect negative effect on productivity through soil compaction, iron toxicity, sulfuric acid and organic acid, lack of oxygen due to the formation of a reductive atmosphere. Reductive conditions result in changes in plant physiological metabolism which in turn decreases productivity compared to normal conditions.

The production and productivity of rice in swamplands are described from the four regencies. Climate change is described in three climatic conditions: normal, El Nino, and La Nina (Table 1). Decreasing in rice productivity in South Kalimantan during El Nino from 3.33 t ha⁻¹ to 3.26 t ha⁻¹ followed by a decrease in the production of 235,583 tons from 1,267,005 tons in normal conditions to
1,031,467 million tons (Table 2). The areas that were strongly affected were those with the most extensive swamp areas, namely Barito Kuala and Banjar Regencies followed by Tanah Laut and Tapin Regencies. Decreasing in rice production because a lot of lands were not harvested. The largest decrease in production occurred in El Nino in 1991 followed by 1997 and 1994. La Nina showed a significant effect on rice productivity and production in South Kalimantan. Rice productivity decreased to an average of 2.68 t ha\(^{-1}\) from 3.33 t ha\(^{-1}\) under normal conditions, only in Barito Kuala Regency the most decreased was at an average of 2.21 t/ha and Banjar Regency an average of 2.56 t ha\(^{-1}\). Rice production in South Kalimantan also showed a decreased from 1,267,005 tons under normal conditions to 1,041,000 tons (Table 2). Productivity decreased significantly in El Nino and La Nina. The impact of El Nino began to be of particular concern since strong El-Nino in 1997, which resulted in rice imports peak of 5 million tons. The importance of anticipating decreasing in production due to El Nino had led to the emergence of Presidential Instruction No. 5/2011 concerning Safeguarding National Rice Producers in extreme conditions. At the national level, the El Nino such as 1972/73, 1982/83, 1991/1992, 1997/98, 2009/2010, and 2015/2016 had consistently resulted in decreased rice production [13]. According to Naylor et al [14] the difference in the area of rice planted in El Nino 1982/1983 and La Nina 1975/1976 was around 800 thousand ha, equivalent to 3.5 million tons of rice or 7% of total annual rice production. During El Nino 1997/1998, there was a decrease in crop yield by 925 thousand ha, so that in the period September 1997 to April 1998 there was a decrease in rice production by about 4.8 million tons.

**Table 1.** Rice production and productivity in tidal swampland (Barito Kuala, Banjar, Tapin and Tanah Laut Regencies) in South Kalimantan under normal, El Nino and La Nina between 1991–2003.

| Regency          | Rice production in Normal (ton) | Rice productivity in Normal (t ha\(^{-1}\)) | Regency          | Rice production in El-Nino (ton) | Rice productivity in El-Nino (t ha\(^{-1}\)) | Regency          | Rice production in La-Nina (ton) | Rice productivity in La Nisa (t ha\(^{-1}\)) |
|------------------|----------------------------------|---------------------------------------------|------------------|----------------------------------|----------------------------------------------|------------------|----------------------------------|---------------------------------------------|
|                  | 2001    | 2002    | 2003    | Average | 2001    | 2002    | 2003    | Average | 1991    | 1994    | 1997    | Average | 1991    | 1994    | 1997    | Average | 1992    | 1995    | 1998    | Average | 1992    | 1995    | 1998    | Average |
| Barito Kuala      | 292,857 | 268,824 | 272,341 | 278,007 | 4.89   | 3.05   | 3.19   | 3.71    | 227,359 | 211,093 | 241,188 | 226,548 | 2.76   | 2.52   | 2.86   | 2.71    | 167,015 | 167,020 | 235,391 | 189,808 | 7.43   | 3.90   | 3.70   | 3.84    |
| Banjar           | 219,997 | 201,381 | 214,741 | 212,039 | 3.35   | 3.33   | 3.59   | 3.42    | 102,081 | 117,796 | 103,084 | 107,654 | 3.26   | 3.12   | 3.00   | 3.13    | 167,015 | 167,020 | 235,391 | 189,808 | 3.90   | 3.70   | 3.93   | 3.84    |
| Tanah Laut       | 102,081 | 117,796 | 103,084 | 107,654 | 3.26   | 3.12   | 3.00   | 3.13    | 167,015 | 167,020 | 235,391 | 189,808 | 3.90   | 3.70   | 3.93   | 3.84    | 167,015 | 167,020 | 235,391 | 189,808 | 3.90   | 3.70   | 3.93   | 3.84    |
| Tapin            | 167,015 | 167,020 | 235,391 | 189,808 | 3.90   | 3.70   | 3.93   | 3.84    | 167,015 | 167,020 | 235,391 | 189,808 | 3.90   | 3.70   | 3.93   | 3.84    | 167,015 | 167,020 | 235,391 | 189,808 | 3.90   | 3.70   | 3.93   | 3.84    |
| South Kalimatan  | 1,272,432| 1,211,594| 1,316,989| 1,267,005| 3.38   | 3.32   | 3.30   | 3.33    | 1,272,432| 1,211,594| 1,316,989| 1,267,005| 3.38   | 3.32   | 3.30   | 3.33    | 1,272,432| 1,211,594| 1,316,989| 1,267,005| 3.38   | 3.32   | 3.30   | 3.33    |

- = no data.

Source: Data modified from Statistical Bureau of Regencies in South Kalimantan (1991–2003).

The fluctuation of rice fields planted in South Kalimantan under normal conditions was around 380,481 ha, in El Nino was an area of 337,697 ha and in La Nina was 388,432 ha. Meanwhile, fluctuation of rice production during normal was 1,267,005 tons, in El Nino was 1,100,893 tons and in
La Nina was 1,041,000 tons per year. So the fluctuation of land use area during El Nino is smaller than normal, while in La Nina it is bigger than normal. This happened because during El Nino in tidal swampland was dry so it could not be planted. Meanwhile, the fluctuation of rice productivity in tidal swamplands of South Kalimantan during El Nino and La Nina was smaller than during normal times 1,041,000 tons per year. So the fluctuation of land use area during El Nino is smaller than normal, while in La Nina it is bigger than normal. This happened because during El Nino in tidal swampland was dry so it could not be planted. Meanwhile, the fluctuation of rice productivity in tidal swamplands of South Kalimantan during El Nino and La Nina was smaller than during normal times.

4. Requirements for rice variety selection

The choice of rice varieties in swamplands is determined by many factors. Based on a review of research results as well as thoughts and knowledge/field experience related to the distribution of high yielding rice varieties, factors that influence the selection of rice varieties in swamplands are high yield potential, tolerant to abiotic stress (adaptability), market demand, preference, plant age, plant height, and pest and disease resistance.

4.1. High yield potential

High yield potential is the main focus in selecting rice varieties in swamplands. In swampy land, the results showed that high yield potential, in addition to adaptability, was an important factor in selecting varieties with a high score of 4.02 [15]. Rice varieties with high yield potential can only be obtained from high yielding varieties (HYV’s). In swamplands, a variety with high yield potential may not necessarily be able to show such yield potential, due to its low adaptability. On the other hand, varieties with low yield potential (local varieties) were often more adaptable.

4.2. Adaptability

In acid sulfate tidal fields, the main stress is high soil Fe and Al concentrations and low pH. The stress in saline soils is salinity, whereas in peatlands there is lack of Cu and Zn micro nutrients. In lowlands the main stress is stagnant water, where-in shallow lowlands there can be drought in the dry season, while in medium and deep wetlands it is deep puddles in the rainy season. The existence of climate change which is increasingly having an impact on drought and deep inundation must be a special consideration in the selection of varieties. Farmers choose rice varieties with a high level of tolerance to soil and water stress, although sometimes the yield potential is relatively low. Adaptation of varieties is a major factor in tidal swamplands so that these HYV’s varieties can be adopted by farmers [16].

4.3. Market demand

The distribution of the dominant varieties is closely related to market demand or high selling prices. The conditions in the tidal lands of South and Central Kalimantan, which are mostly planted with local varieties, are due to the high selling price [7]. Moreover, it often happens that buyers are waiting at the edge of the rice fields for the farmers’ rice harvest.

4.4. Preference

The preference factor is related to the high selling price. Between areas in swampland areas there are different preferences for a variety. In swamps, Sumatra and Sulawesi generally prefer varieties with a fluffier rice texture, on the other hand, in South and Central Kalimantan, the rice texture is dry. Apart from the texture of the rice, things that also determine this preference are clear and translucent rice, as well as the small-lean grain size. The results of the preference test for Inpara varieties showed that 75% of respondents chose varieties with long slender grain shapes and 60% liked the taste/texture of dry rice [17]. The varieties with high yield potential and the preferred taste of rice are chosen by the farmers.
Table 2. Description of rice varieties Inpari 12, 13, 18, 19, and Inpari 20.

| Description       | Inpari 12   | Inpari 13   | Inpari 18   | Inpari 19   | Inpari 20   |
|-------------------|------------|-------------|-------------|-------------|-------------|
| No. Selection     | OM2395     | OM1490      | B10970C-MR-4-2-1-1-1-Si-3-2-4-1 | B11283-6C-PN-5-MR-2-3-Si-1-2-1-1 | BP2080-2E-KN-6-1 |
| Crossing          | IR63356-SEL/TN1 | OM606/IR18348-36-3-3 | BP364B-33-3-PN-5-1/Bio530B-45-9-3-1 | BP342B-MR-1-3/ BP226E-MR-76 | S2823E-KN-33/IR64/ S2823E-KN/33 |
| Plant duration    | ±99 days   | ±99 days    | ±102 days   | 104 days    | ±104 days   |
| Plant shape       | Erect      | Erect       | Erect       | Erect       | Erect       |
| Plant height      | ±99 cm     | ±102 cm     | ±93 cm      | 102 cm      | ±102 cm     |
| Flag leaf         | Erect      | Erect       | Erect       | Erect       | Erect       |
| Grain shape       | Slender    | Long-slower | Long-slower | Long-slower | Slender     |
| Grain colour      | Straw      | Straw       | Straw       | Straw       | Straw       |
| Thresholdability  | Intermediate | Intermediate | Intermediate | Intermediate | Intermediate |
| Lodging           | -          | -           | No lodged   | No lodged   | No lodged   |
| Rice texture      | Soft       | Soft        | Soft        | Soft        | Soft        |
| Amylose content   | 26.4 %     | 22.40 %     | 18.0 %      | 18.0 %      | 21.1 %      |
| Glycemic index    | 53         | 45          | -           | -           | -           |
| 1000 grain weight | 27 grams   | 25.2 grams  | 29 grams    | 25 grams    | 25.6 grams  |
| Yield average     | 6.2 t ha⁻¹ | 6.6 t ha⁻¹  | 6.7 t ha⁻¹  | 6.7 t ha⁻¹  | 6.4 t ha⁻¹  |
| Yield potential   | 8.0 t ha⁻¹ | 8.0 t ha⁻¹  | 9.5 t ha⁻¹  | 9.5 t ha⁻¹  | 8.8 t ha⁻¹  |
| Resistance to pest| Resistance BPH-1, 2, 3 | Resistance BPH 1, 2, more resistance BPH-3; | Resistance BPH biotype 1, 2, more resistance biotype 3. | Resistance BPH biotype 3. | More resistance BPH biotype 1, more susceptible biotype 2, 3 |
| Resistance to diseases | More resistance HDB III, IV, VII, Resistance blas ras 033, More resistance blas ras 133 and 073, susceptible tungro. | More susceptible HDB patotype III, more resistance patotype IV, susceptible patotype VIII | Resistance HDB patotype III, more resistance patotype IV, susceptible patotype VIII | Resistance HDB patotype III, more resistance patotype IV, susceptible patotype VIII | Resistance HDB patotype III, more susceptible patotype IV, VIII, susceptible tungro, more resistance blas ras 033, susceptible ras 133, 073, 173. |
4.5. Plant old and height
The age criteria for rice plants are deep (> 165 days), medium (125-164 days), early (105-124 days), very early (90-104 days), and ultra-early (<90 days). Plant age determines the cropping index (IP), where early or very early varieties can increase the IP to 300 or 400. In swamps, very early age is important to deal with the occurrence of salinity in type A tidal swamplands and the occurrence of drought in swampland, shallow in the dry season.

Although tall plants can reduce the interception of sunlight to the lower leaves, in swamps this property is quite important. Based on the Standard Evaluation System for Rice [18], the height of rice plants is classified into three (3) groups, namely low (<100 cm), medium (110-130 cm), and high (>130 cm). Tall plants can compensate for the height of inundation in paddy fields, especially type A tidal fields and intermediate lowlands during the rainy season. Tall plants allow the rice panicles to be above the puddle and can develop well.

4.6. Resistance to pests and diseases
The main pests that attack rice plants are rats and brown planthoppers, while the main diseases are tungro, blast, and bacterial leaf blight. The results of observations on tungro and blast attacks on Inpara's superior varieties showed that Inpara 5 was attacked by blast and Inpara 1 was attacked by tungro, while Inpara 4 was resistant to both diseases [19]. The selection of varieties that are resistant to pests and diseases will accelerate the spread of new high yielding varieties of rice in swamplands.

5. Selection of early maturity drought tolerant rice varieties
During El Nino, very early maturity varieties can be planted such as Inpari 12 and 13 which are 99 days old, or Inpari 18, 19 and 20 which are 102-104 days old. Varieties that are mildly drought tolerant include Inpari 38, 39, and 40 [20]. Because of their early maturity, these varieties are expected to be able to escape from drought, especially just before flowering (Table 2).

6. Selection strategy of rice varieties for submergence tolerance
During the rainy season, especially during la nina, the selection of varieties is more limited due to deep inundation conditions. Inpara varieties 3, 4 and 5 or Inpari 29 and 30 can be planted. Inpara 3 withstands submergence for 6 days, Inpara 4 and Inpara 5 each could withstand submergence for 14 days. Likewise, Inpari 29 and Inpari-30 Ciberang Sub-1 can withstand 14 and 15 days of submengence, respectively [21]. It is not recommended to plant other Inpara varieties, let alone the Inpari variety during the la nina in middle freshwater swamplands.

In deep freshwater swampland, almost all high yielding varieties and local varieties of rice cannot be planted. ISARI (formerly LP3 Banjarmasin) once released the Tapus, Alabio and Nagara varieties or deep water rice. These three varieties have been planted in deep fields and were successfully harvested by boat or canoe. These varieties can elongate and form book shoots, and can be planted in deep deep fields (150 cm inundation with an increase in inundation of 1-3.5 cm per day). Despite the limited variety of rice that can be planted on deep deep fields, this land can be a boon for local communities if El Nino arrives. At the time of el nino, this land was very fertile for rice growth so that it could become a granary for rice during other fields of drought and puso cultivation [21] (Table 3).
Tabel 3. Description of rice varieties Inpara 3, 4, 5, Inpari 29, dan Inpari 30 Cihang Sub-1.

| Description       | Inpara 3                  | Inpara 4                  | Inpara 5                  | Inpari 29                  | Inpari 30                  |
|-------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| No. Selection     | IR70213-9-CPA-12-UBN-2-1-3-1 | IR05F101                 | IR07F102                 | B13138-7-MR-2-KA-1       | Cihang/IR64Sub1/Cihang    |
| Crossing          | Introduktion from IRRI    | Introduktion from IRRI    |                          | IR69502-6-SKN-UBN-1-B-1-3-KAL-9418F/Pokhari/Angeke |                      |
| Plant duration    | 127 days                  | 135 days                  | 115 days                 | ±110 days                | 111 days                  |
| Plant shape       | Erect                     | Erect                     | Erect                    | Erect                    | Erect                     |
| Plant height      | 108 cm                    | 94 cm                     | 92 cm                    | ±103 cm                  | Eret                     |
| Flag leaf         | Erect                     | Intermediate              | Intermediate             | Long-slimder             | Light-slimder             |
| Grain shape       | Intermediate              | Intermediate              | Intermediate             | Intermediate             | Intermediate             |
| Grain colour      | Straw                     | Straw                     | Intermediate             | Intermediate             | Intermediate             |
| Thresholdability  | Intermediate              | No lodged                 | Intermediate             | Soft                     | Soft                     |
| Lodging           | Hard                      | Hard                      | Hard                     | ±21.1 %                  | ±22.4 %                  |
| Rice texture      | Hard                      |                           |                          |                         |                          |
| Amylose content   | 28.60%                    | 29%                       | 25.20%                   |                          |                          |
| Glycemic index    | -                         | -                         | -                        | -                        |                          |
| 1000 grain weight | -                         | -                         | -                        | 25 grams                 | 27 grams                 |
| Yield average     | 4.6 t ha\(^{-1}\)         | 4.7 t ha\(^{-1}\)         | 4.5 t ha\(^{-1}\)        | 6.5 t ha\(^{-1}\)       | 7.2 t ha\(^{-1}\)        |
| Yield potential   | 5.6 t ha\(^{-1}\)         | 7.6 t ha\(^{-1}\)         | 7.2 t ha\(^{-1}\)        | 9.5 t ha\(^{-1}\)       | 9.6 t ha\(^{-1}\)        |
| Resistance to pest | More resistance to BPH biotype 3 | More resistance to BPH biotype 3 | More susceptible to BPH biotype 3 | More susceptible to BPH biotype 3, Susceptible to biotype 2 and 3 | More susceptible to BPH biotype 3, Susceptible to biotype 3. More susceptible to leaf hawar bacteria patotype III. Susceptible to patotype IV and VIII. |
| Resistance to diseases | Resistance to leaf hawar patotype IV and VIII. | Resistance to leaf hawar patotype IV and VIII. | Resistance to leaf hawar patotype IV and VIII. | Resistance to leaf hawar patotype IV and VIII. | Resistance to leaf hawar patotype IV and VIII. |

7. Conclusion
The strategy for selecting the right variety in swamplands is very important so that the difference between potential yield and factual yield is not wide. Selection of accurate varieties will increase rice yields and productivity of swamps. Variety selection is determined by factors of high yield potential, abiotic stress tolerance, market demand, preferences, age and plant height, and resistance to pests and
plant diseases. Selection of rice varieties when El nino can use early maturity or drought tolerant varieties, while at the La nina can use submergence tolerant rice.

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