The fluctuation of rice production of tidal swampland on climate change condition (Case of South Kalimantan Province in Indonesia)

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Abstract. Indonesia has a wet tropical climate which is part of its territory crossed by the equator. The rice planting period in Indonesia follows the climatic conditions generally divided into two planting seasons, namely the rainy season from October to March and the dry season from April to September. Almost every 3 to 5 years extreme climate changes occur namely El-Nino and La-Nina which have an impact on rice production. Nationally, the extreme climate phenomenon above showed the effect on rice production. El-Nino during the year 1970–2010 was reported to cause a decrease in rice production around -4.08%, while La-Nina in the same period caused an increase in production by about 1.78%. However, the two extreme climatic conditions had reduced rice productivity by -0.50% and -0.65%, respectively. Most of the tidal swamplands have long been cleared and used for the cultivation of lowland rice. In an effort to optimize tidal swampland as a source of rice production in the future, several strategic actions are needed. The purpose of this paper is to uncover the effects of extreme climate change (El-Nino and La-Nina) on rice production and productivity in tidal swamplands and strategic efforts to overcome the decline in rice production due to the extreme climate changes.

1. Introduction

Recently, rice fields in Indonesia had been shrinking from year to year due to the quick conversion of land functions. In 1981 Indonesia's rice fields reached 9.38 million ha, increased in 1990 to 10.50 million ha, and in 1996 to 11.44 million ha, then decreased in 2000 to 7.75 million ha. Although there was a reduction in the area of paddy fields, there was an increase in rice productivity from an average of 2.36-2.65 t/ha in 1970 to 3.29-3.58 t/ha in 1980, 4.30-4.47 t/ha in 1990, 4.35 t/ha in 1995, 4.63 t/ha in 2000. Nationally, the highest average rice productivity was 5.0-5.5 t/ha on irrigated rice fields [1].

Rice fields in Indonesia generally have two planting seasons that are rainy season (October to March) and the dry season (April to September). Almost every 3 to 5 years there was an extreme climate change - El Nino and La Nina - which affects rice production. The climate phenomenon in Indonesia showed a strong influence on rice production. Extreme climates El Nino during 2007-2010 were reported to have caused a decrease in rice production by around -4.08%, on the other hand, La Nina in the same period led to an increase in production of around 1.78%. However, two extreme climatic conditions have reduced rice productivity by -0.50% and -0.65%, respectively [2].

The potential of tidal swampland in South Kalimantan is around 553,551 hectares, which are spread mostly in regencies of Barito Kuala (239,830 ha), Banjar (52,592 ha), Tanah Laut (80,467 ha), and Tapin (102,322 ha) [3][4]. A survey in 2019 showed a change in swampland distribution, so that Barito Kuala, Banjar, Tanah Laut, and Tapin Regencies became 226,899 ha, 74,273 ha, 56,430 ha, and 37,295 ha,
respectively [5]. Most of the tidal swampland have long been cleared and used for lowland rice cultivation. In an effort to optimize tidal swampland as a source of rice production, several strategic actions are needed. The purpose of this paper is to review the effects of climate change (El-Nino and La-Nina) on rice production and productivity in tidal swampland strategic measures to overcome the decline in rice production due to the extreme climate.

2. Rice production and land productivity in tidal swampland

The productivity of swamplands was different from one another because each had levels and types of constraints. Of four swampland typologies, the highest rice productivity was potential land that has small production constraints (pyrite depth layer >50 cm) with rice yields of 3.2-6.3 t/ha, followed by shallow-to medium peat which are moderate production constraints with rice yields of 2.7-5.2 t/ha, and finally, acid sulfate soils which are high constraints of rice production with yields of 2.6-4.6 t/ha [6][7].

According to Noor and Saragih [8], Noor [6], Koesrini et al [7], Khairullah and Noor [9] productivity level of tidal swamplands was influenced by many factors, including soil and water management, amelioration, fertilization, varieties, cultivation techniques, and pest and disease control. According to Noor and Saragih [8], and Noor [6] from additional rice productivity of 100% water management could contribute 20-70%, soil tillage 18%, fertilizing 8%, and lime 23%, lime residue 8%, and rainfall 23%.

The tidal swampland that has been reclaimed is around 2,832,814 ha, but not all of the swampland is planted. The planted tidal swampland was only 830,439 ha and monotonous swamps were around 351,325 ha [10]. About 90% of tidal swampland has a cropping intensity of one time a year (planting index (PI) 100). By increasing cropping intensity twice a year (PI 200) and productivity level of tidal swampland by optimal water and land management can reach 4.0 t/ha/season.

If the swampland target is 570,000 ha (about 50% of reclaimed swampland) with a productivity of 4 t/ha, additional production of around 2.28 million tons per year will be obtained. From abandoned swampland target of 410,000 ha (50% of abandoned swampland) and planted by rice with a productivity of 4 t/ha, additional production of about 1.23 million tons per year is obtained [10]. According to Sulaiman et al [11] if an area of 1.15 million swamplands of 10 provinces has been reclaimed at PI 100 to PI 200 the rice production additional 3.5 million tons per year.

The current contribution of rice production from tidal swamplands is still low, estimated to 600-700 thousand tons per year or 1.5% of national production (62.56 million tons with an average 4.5 t/ha). The low productivity was due to rice cultivation in swamplands faced various problems, including land agro-physical, environmental, socio-economic cultural, and local cultural [12].

3. The fluctuation of rice production at swampland of South Kalimantan due to climate change

3.1. Extreme climate phenomenon in Indonesia

The extreme climate change in Indonesia was a shorter interval [13]. Food crop, especially rice is the most vulnerable to extreme climate, El Nino and La Nina. During 70 years, Indonesia was hit by 18 El Nino, including three very strong, four strong and moderate, and seven weak El Nino and 15 La Nina including four strong, five moderate, and six weak La Nina (Figure 1) [14].

The extreme climate will affect rice production because during El Nino most rice fields suffered drought until puso but during La Nina, some rice fields were flooded so that it cannot be planted. However, El Nino in swamplands could be a blessing because in swamplands become dry so that it can be planted and can lead to additional planting areas [13]. A survey in 2013 showed that extreme climate in 1970-2010 resulted in decreasing in national rice production by -0.50% (El Nino) and -0.65% (La Nina) [2].
Changes in rainfall patterns and extreme climate are very influential on rice. The vulnerability of rice plants was closely related to land use systems and soil properties, cropping patterns, soil management, water, crops, and varieties [15]. Therefore, the vulnerability of rice plants to rainfall patterns would have an impact on the area of planting and harvesting, yield productivity and quality. El Nino or La Nina caused 1) crop failure, decrease in planting index (PI) which leads to decreased productivity and production, 2) damage to agricultural land resources, 3) increase in frequency, area, and intensity of drought, 4) increased humidity, and 5) increased intensity of plant pests [16].

Drought, flooding, and shifting rainfall change had reduced rice production. Research and Development of Consortium Climate Change IAARD predict climate change El Nino will expand the area of crops that are threatened with drought for lowland rice from 0.3-1.4 % to 3.1-7.8%, while area putso due to drought increased from 0.04-0.41% to 0.04-1.87%. The frequency of drought in lowland rice cultivation was three times in four years and generally increases sharply in El Nino years, while the frequency of flood ranged from 2-3 times to a sharp increase in La Nina years [17]. Increased flood intensity would indirectly affect rice production due to increased attacks by plant pests, such as brown planthoppers [18]. Research results of ISARI in 2012 showed that attacks of tungro, rats, and stemborer increased when rainfall amount >200 mm. Brown planthopper attacks increased in rainfall of 100-150 mm, while blast disease increased in rainfall> 200 mm [19].

Increasing in temperature increases the rate of transpiration which reduced rice productivity, increased water consumption, accelerates fruit or seed ripening, reduced yield quality, and the development of various pests. The results of Tschirley [20] research showed that there had been a decrease in agricultural yields of more than 20% when temperature rise more than 4°C. The Research and Development of Consortium Climate Change (KP3I) [21] showed that an increase in temperature due to an increase in CO2 concentration would reduce crop yields. If the paddy field conversion rate was 0.77% per year and there was no increase in planting index, then rice production at the Regency level in 2025 will decrease by 42,500-162,500 tons.

Increasing temperature also affects population and pest attacks. The impact of rising sea levels on a decreased in rice production due to an increase in salinity. According to Grattan et al [22], salinity levels below 2.0 dS/m did not affect rice yield. If salinity increases above 2 dS/m then rice yield will decrease by about 10% for every 1 dS/m increase.

### 3.2. Climate stress on swampland 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.

3.3. Fluctuations in rice production due to climate change
A survey by [5] showed that area of swampland in Regencies of Barito Kuala was 226,899 ha (41% of swampland area of rice fields), Banjar 74,273 (13%), Tanah Laut 56,430 ha (0.10%), and Tapin was 37,295 ha (0.07%) of total swampland area in South Kalimantan (around 553,551 ha). The swamplands of the four regencies cover around 434,857 ha (75.56%) of tidal swampland in South Kalimantan (Table 1).

Table 1. Area of tidal swampland in Barito Kuala, Tanah Laut, Banjar and Tapin regencies based on hydrotopography 2019 [5].

| Regency       | Type A | Type B | Type C | Type D | Total (ha) |
|---------------|--------|--------|--------|--------|------------|
| Barito Kuala  | 30,337 | 62,243 | 115,171| 19,148 | 226,899    |
| Banjar        | 5,534  | 32,204 | 36,530 | 5      | 74,273     |
| Tanah Laut    | 19963  | 30,243 | 4,763  | 1,461  | 56,430     |
| Tapin         | 0      | 19,330 | 17,964 | 0      | 37,295     |
| South Kalimantan* | 182,188 | 172,776 | 177,970 | 20,617 | 553,551 |

*) covered 10 regencies/city of South Kalimantan

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 2). Decreasing in rice productivity in South Kalimantan during El Nino from 3.33 t/ha to 3.26 t/ha 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 was not harvested. The largest decrease in production occurred in El Nino 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 from 3.33 t/ha 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. 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 [14]. According to Naylor et al [23] 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.

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.

Table 2. 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) |
|------------------|---------------------------------|-----------------------------------|
|                  | 2001               | 2002               | 2003               | Average | 2001 | 2002 | 2003 | Average |
| Barito Kuala     | 292,857            | 268,824            | 272,341            | 278,007 | 4.89 | 3.05 | 3.19 | 3.71 |
| Banjar           | 219,997            | 201,381            | 214,741            | 212,039 | 3.35 | 3.33 | 3.59 | 3.42 |
| Tanah Laut       | 102,081            | 117,796            | 103,084            | 107,654 | 3.26 | 3.12 | 3.00 | 3.13 |
| Tapin            | 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 |

| Regency          | Rice production in El-Nino (ton) | Rice productivity in El-Nino (t/ha) |
|------------------|----------------------------------|-------------------------------------|
|                  | 1991               | 1994               | 1997               | Average | 1991 | 1994 | 1997 | Average |
| Barito Kuala     | 227,359            | 211,098            | 241,188            | 226,548 | 2.76 | 2.52 | 2.86 | 2.71 |
| Banjar           | 142,390            | 137,268            | 145,257            | 141,638 | 2.40 | 2.05 | 2.95 | 2.47 |
| Tanah Laut       | 101,682            | 114,022            | -                  | 107,852 | 2.67 | 2.74 | -    | 2.70 |
| Tapin            | 114,634            | 104,397            | 147,951            | 122,327 | 3.34 | 2.46 | 3.48 | 3.09 |
| South Kalimatan  | 953,205            | 1,040,304          | 1,100,893          | 1,031,467 | 2.88 | 2.97 | 3.93 | 3.26 |

| Regency          | Rice production in La-Nina (ton) | Rice productivity in La-Nina (t/ha) |
|------------------|----------------------------------|-------------------------------------|
|                  | 1992               | 1995               | 1998               | Average | 1992 | 1995 | 1998 | Average |
| Barito Kuala     | -                  | 212,786            | 125,050            | 168,918 | 2.28 | 2.15 | 2.21 |
| Banjar           | 176,883            | 167,814            | 155,379            | 166,692 | 2.76 | 2.41 | 2.51 | 2.56 |
| Tanah Laut       | 128,429            | 133,096            | -                  | 130,762 | 2.80 | 3.02 | -    | 2.91 |
| Tapin            | 113,651            | 157,001            | 164,944            | 145,199 | 3.37 | 4.17 | 3.36 | 3.63 |
| South Kalimatan  | 1,092,702          | 1,077,797          | 952,500            | 1,041,000 | 3.00 | 3.00 | 2.03 | 2.68 |

= no data

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

3.4. Strategy for handling extreme climate impacts

There are two approaches to handling El Nino and La Nina, i.e. (1) structurally, namely construction and improvement of water infrastructure, land development and water management technology, and development of drought or submergence resistant rice varieties; and (2) non-structural, namely developing information systems, communication, and preparation of tools, preparation of guidelines and institutional strengthening as well as mapping and identification of areas prone to drought or flooding [14].

Several high yielding varieties (HYV’s) released by IAARD to tolerate submergence such as Inpara-3 which was tolerant of up to 7 days, Inpara-4 and Inpara-5 were tolerant of submergence for up to 14 days. Inpago 5 was a HYV’s upland rice variety that is drought tolerant and capable of producing 6 t/ha. Inpadi 10 was tolerant of drought with a potential yield of 7 t/ha, resistant to brown planthoppers, and bacterial leaf blight (HDB) strain III.

In addition, IAARD has released four HYV’s of very early maturity like Inpari-1, Inpari-11, Inpari-12, and Inpari-13. The use of these varieties could anticipate plants of drought. The Banyuasin variety was tolerant to high salinity, and have developed in several tidal swamplands, including in South Sumatera. This variety was resistant to blast disease, slightly resistant to brown planthopper biotype 3 and HDB strain III. The Lambur variety for saline soil also has blast resistance and it was tolerant of Fe and Al toxicity. Margasari and Martapura were a cross between local and HYV’s were tolerant to soil
acidity and iron toxicity in acid sulfate soils of tidal swamplands. Other HYV’s for swamps such as Inpara 1 and Inpara 2 were also tolerant to iron toxicity and had high yield potential.

4. Conclusion
In general extreme climatic have a strong influence on rice production in tidal swampland. Adequate rice yield potential of swamps can only be achieved with sufficient input and adaptive cultivation techniques in tidal swamland conditions. Rice production in tidal fields of South Kalimantan in El Nino and La Nina decreased by 81.4% (1,031,467 tons) and 82.2% (1,041,000 tons) respectively compared to normal conditions (1,267,005 tons).

There are two approaches to handling El Nino and La Nina, i.e. (1) structurally with improving water infrastructure, developing land and water management technologies, and developing drought and submergence tolerant rice varieties; (2) non-structural with development of information systems, communication, institutional strengthening and mapping and identification of drought or flood prone areas. Water management has a significant effect in increasing production so that farmers could increase planting index (PI) from PI 100 to PI 180 or PI 200. By achieving good productivity and production, swampland management can be sustainable so that the conversion of paddy fields into other land use can be avoided. The fluctuation of tidal swampland use in South Kalimantan during El Nino was smaller than normal, while in La Nina was greater than normal. Meanwhile, the fluctuation of rice productivity during El Nino and La Nina was smaller than during normal conditions.

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