Opportunities for improving rice production in sub-optimal lands South Kalimantan

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Abstract. The wetland agroecosystem in South Kalimantan is very diverse and mostly is sub-optimal land such as rainfed area of 172,074 ha, tidal swamp 188,908 ha, swamp area 135,504 ha, while irrigated paddy fields are only 55,116 ha. Paddy fields that have been planted with rice and can be harvested in 2017 covering an area of 506,126 ha with average productivity of 4.46 t/ha resulting in a total grain of 2,258,261 tons. The productivity of lowland rice in South Kalimantan is still below the average national rice productivity which reaches 5.18 t/ha. The constraints on the production of wetland rice in South Kalimantan vary depending on the type of land such as fluctuations in water (flooding, droughts), acid soils, the presence of toxicity of elements, not yet optimal water management in the swamps land, drought, nutrient deficiency in rainfed land. The area of upland rice plantations in the dryland of South Kalimantan is 63,170 ha, generally local varieties with average productivity of 3.07 t/ha. The development obstacles of upland rice in dryland include soil acidity, low organic matter, nutrient deficiency, competition in land use with other food crops and plantation crops. Rice production in South Kalimantan still has the opportunity to increase in the planting area and productivity. With the gap exist between rice productivity and the potential yield of new superior varieties, the use of other cultivation technologies application still provide opportunities to increase rice productivity in South Kalimantan. The addition of lowland rice planting area can be done by utilizing un-cultivated paddy fields (74,817 ha), the increase in planting index (PI) which is still low (PI 200 is only 9.14%). The addition of upland rice fields can be done on dryland fields with an area of 345,669 ha, or intercropping on plantation land (rubber, oil palm) that has not yet produced (183,539 ha).

1. Introduction
The rice production is increasing year by year following high demand for food consumption. The increase of rice production can be done by the addition of the new rice cultivation area or increasing the planting area by enhancing the cropping index from one time planting to twice. The increase of production can also be done with productivity enhancement by using technological innovations like using superior seeds that are adaptive, fertilization, pest control and output decreased on harvest time or post-harvest.

South Kalimantan has an area of 3.752 million ha, that consists of dryland 2.655 million ha (70.76%) and wetland 1.097 million ha (29.24%). Lands that are suitable for food crops planting in the wetland is 759,776 ha (20.25%), and for food crops planting in dryland of 769,948 ha (20.52%), land that is suitable for yearly planting/farm/intercropping has an area of 688,032 ha (18.34%) [1].
Paddy crops in South Kalimantan is planted on two agroecosystems, paddy’s field (506,126 ha) that consists of rain-fed rice fields, and tidal swampland and swampy land, also upland rice in dryland with an area of 63,170 ha [2]. Paddy’s productivity in sub-optimal lands like rain-fed rice fields, tidal swampland and dry land generally still low. The low productivity in rain-fed rice fields caused by low soil fertility and limited water availability because of rain fluctuation that sometimes uncertain until and it is sensitive to dryness. Tidal swampland has low productivity because the land condition is acid, there are high toxicity elements, sometimes the water is hard to control because of the water infrastructure and water management still nonoptimal.

Low productivity of upland rice in dry land caused by low soil fertility, nutrient deficiency N, P, K, and low level of soil organic source, land to erosion, sensitive to dryness because uneven and fluctuating rainfall distributed. Upland rice planting also facing the competition of land uses between food plants with farm plants like rubber tree and palm tree. Dry land is a potential to produce enough foodstuffs and varies, not just upland rice but also other food’s plants, if managed by using effective technology and the right cultivation strategy [3].

Rice productivity in South Kalimantan that also still low caused by land biophysical constraints, rice cultivation technology in farmer level still incorrect, the use of local varieties with low potential. Rice production in South Kalimantan as much as 2,258,261 ton grain [4], can still be increased with the expansion of planting area, increasing the rice planting index and using technology like superior varieties adaptive location specific, balanced fertilization.

2. Land Potential for Rice Production

2.1. Paddy’s Field

South Kalimantan has diverse agroecosystem and has potential to produce rice like irrigated land and sub-optimal land like rain-fed rice fields, tidal swampland and swampy land, dry land with wet climate that generally act sourly. Tidal swampland has the largest area (188,908 ha, followed by rain-fed rice fields 172,074 ha) and swampy land with 135,604 ha. The largest rain-fed rice fields found in Balangan districts, largest tidal swampland found in Hulu Sungai Utara districts and Hulu Sungai Selatan (Table 1).

Table 1. Rice field area based on agroecosystem type for each districts in South Kalimantan.

| No | City/Districts       | Irrigated (ha) | Rainfed (ha) | Tidal Swampland (ha) | Swampy Land (ha) | Total (ha) |
|----|----------------------|----------------|--------------|----------------------|-----------------|------------|
| 1  | Tanah Laut           | 6,860          | 24,449       | 15,628               | 28,761          | 75,698     |
| 2  | Kotabaru             | 4,950          | 22,815       | 4,210                | -               | 31,975     |
| 3  | Banjar               | 7,375          | 15,090       | 35,135               | 11,868          | 69,468     |
| 4  | Barito Kuala         | -              | -            | 113,998              | -               | 113,998    |
| 5  | Tapin                | 3,901          | 25,859       | 17,265               | 18,942          | 65,967     |
| 6  | Hulu Sungai Selatan  | 6,317          | 10,358       | -                    | 29,019          | 45,694     |
| 7  | Hulu Sungai Tengah   | 15,641         | 15,092       | -                    | 7,737           | 38,470     |
| 8  | Hulu Sungai Utara    | 6,050          | 623          | -                    | 29,378          | 36,051     |
| 9  | Tabalong             | 1,827          | 8,332        | -                    | 5,352           | 15,511     |
| 10 | Tanah Bumlu          | 225            | 17,226       | 307                  | -               | 17,758     |
| 11 | Balangan             | 1,970          | 29,266       | -                    | 3,037           | 34,273     |
| 12 | Banjarmasin          | -              | -            | 1,988                | -               | 1,988      |
| 13 | Banjarbaru           | -              | 2,964        | 377                  | 1,510           | 4,851      |
|    | **Total (Ha)**       | **55,116**     | **172,074**  | **188,908**          | **135,604**     | **551,702** |

Source by: [5]

In South Kalimantan rice planting index (PI) still low, average two-times planting (PI 200) just reached 9.14%, highest two-times planting in the irrigated rice field, meanwhile two-times planting in
the rain-fed rice field, swampy land and tidal swamp poorer (Table 2). Not all fields were used for rice planting or any other plants, there are still fields that have not been planting at all of 74,817 ha (Table 2).

Table 2. The use of fields for rice plant in South Kalimantan

| No | Irrigation Type          | Planting Frequency | Not planted with rice | Not planted with anything | Total (Ha) |
|----|-------------------------|--------------------|-----------------------|---------------------------|------------|
| 1  | Irrigated lowland       | 31,529             | 16,348                | 4,736                     | 2503       | 55,116 |
| 2  | Rain-fed                | 126,337            | 13,252                | 9,121                     | 23,364     | 172,074 |
| 3  | Tidal Swampland         | 156,480            | 9,844                 | 5,684                     | 16,900     | 188,908 |
| 4  | Swampy                  | 94,652             | 1,710                 | 7,192                     | 32,050     | 135,604 |
|    | Total (Ha)              | 408,998            | 41,154                | 26,733                    | 74,817     | 551,702 |

Source by: [5]

Rice fields planting area in South Kalimantan for the last five years has been increased from 416,675 ha (2015) to 506,823 ha (2017) or increased by 21.6%. Rice fields productivity in South Kalimantan since 2013 tend to stay the same, even experiencing slowing productivity until 2016. In 2013 rice productivity 4.35 t/ha started to rise, in 2017 became 4.46 t/ha (Figure 1).

![Figure 1. The growth of planting area and irrigated rice fields productivity in South Kalimantan for the last five years.](source)

Source by:[2, 4, 6, 7, 8]

2.2. Dry Land

The use of land for non-fields (dry land) in South Kalimantan, the use for farming fields has the largest (672,659 ha), moor/farm/field/ that uses for food planting around 345,669 ha, meanwhile dry land that temporary has not been cultivated is 154,237 ha (Table 3).
Table 3. The use of non-fields land in South Kalimantan

| Type of lands use                  | Land Area (ha) |
|-----------------------------------|----------------|
| Moor/farm/field                   | 345,669        |
| Plantation                        | 672,659        |
| Community Forest                  | 177,726        |
| Grazing Pasturage Field           | 160,778        |
| Temporary Land that has not been cultivated | 154,237 |
| Others (pond, pool, dyke, state forest, etc) | 711,692 |

Source by: [5]

Upland rice cultivated in dry land on moor/farm/field land in open field as well as intercropping or as intercropped yearly land or plantation. The area of upland rice in dry land for the last 5 years tend to increase from 2013 (50,935 ha) until 2016 (66,135 ha), then experiencing planting area reduction in 2017 (63,170 ha). Thus also the productivity in 2013 (3.12 t/ha) increased in 2016 (3.52 t/ha) and decreasing in 2017 (3.02 t/ha) (Figure 2).

![Figure 2](image)

Source by: : [2, 4, 6, 7, 8]

Figure 2. The growth of planting area and productivity of upland rice in South Kalimantan for the last 5 years.

Rubber and palm plantation crops are dryland commodity that cultivated large enough in South Kalimantan. Not all plants produce, there are also crops that have not produced that age < 4 years around 197,574 ha. Fields under palm plantation that has not yet productive can be used for upland rice planting as an intercropped plant (Table 4).

Table 4. The use of land for plantation in South Kalimantan

| No | Type of Plants | TBM (Ha) | TM (Ha) | TTR (Ha) | Total (Ha) |
|----|----------------|----------|---------|----------|------------|
| 1  | Rubber         | 83,035   | 173,392 | 14,582   | 271,009    |
| 2  | Palm           | 100,504  | 293,716 | 1,308    | 395,528    |
| 3  | Coconut        | 6,069    | 29,047  | 4,478    | 39,594     |
| 4  | Other Plants   | 7,966    | 12,482  | 3,055    | 23,503     |
| **Total** |             | **197,574** | **508,637** | **23,423**     |

TBM = Earliar growing plants, TM = Produced plants, TTR = Damaged old plants. Source by: [2]
The result of this research showing that the use of land for plantation like palm and rubber can be potentially cultivated for food plants and horticulture and animal feed that worked by alley cropping/agroforestry system. Agroforestry plantation system (wanatani/agroforestry) not just for expanding the farmer’s income but also very beneficial in terms of (1) reducing the crop failure from one commodity; (2) to decrease the rate of erosion; (3) decrease the needs of labor by the cultivation application without tillage or legumes animal feed’s planting; and (4) increasing the efficiency of water use and nutrient. Plants that common for cultivation as the intercropping plant under yearly plants are upland rice, nuts, and vegetables. Planting patterns should be referred based on upland rice patterns, that is upland rice-soy bean-cowpea/green bean. The maximum limit of upland rice that can be planted as an intercropped plant with perennials, if the shade for staple food hits 50%.

South Kalimantan has climate characteristics that support agricultural development with: Wet months = 6 months, and dry months = 2 months. The temperature relatively stable 26-28 °C (Figure 3). This climate characteristics enabling for cropping patterns development and increasing plantation index.

3. The Obstacles of Rice Production in South Kalimantan

In use of sub-optimal land for paddy production facing few obstacles, whether land’s physic or social economy. Biophysical obstacles encountered in paddy field sub-optimal like puddle fluctuation (flooded, dryness), the low road access to the location, nonoptimal water system mainly in the swamp area. In tidal swamp field, paddy productivity still low especially caused by the low soil fertilization, nutrient deficiency, very acidic soil, poisonous Al, Fe and H₂S.

One limiting factor for rice cultivation in paddy fields is iron toxicity, which has been reported to occur extensively in several Asian countries such as China, India, Indonesia, Thailand, Malaysia, and the Philippines. In rice plants that are exposed to symptoms of severe iron toxicity resulting in very poor plant growth, tillers do not grow so that the results obtained are very low and can even lead to crop failure. The use of superior variety that is intolerant in tidal swamp field caused the farmer to plant a lot of local paddies that are more tolerant to the condition of tidal swamp field. The research results showet that the use of rice genotype that is more sensitive can cause iron toxicity and in certain cases can even lead to crops failure.

Tidal swamp field in South Kalimantan has an area of 188,908 ha this has the potential for rice development, with 100,348 ha that has been planted with paddy. Barito Kuala is a district in South Kalimantan and it has the biggest agricultural land with tidal swamp field that reached new
productivity by 3.33 t/ha [2]. One of the reason productivity of rice in tidal swamp field still low caused by the high level of Fe and soil acidity, low soil nutrient level, land that always flooded [17].

In swampy land, rice farming the barriers are (i) the water regime is fluctuating and unpredictable, (ii) flooded in raining season and dryness in drought season, and (iii) the characteristics of physicochemistry and soil fertility also micro hydrotopography of the land is diverse and generally unorganized [18], so that paddy plant can’t grow and produce optimally.

The obstacles of rice production in dryland (upland rice) like the competition between crops and farm, wavy topography, prone to erosion, soil acidity, nutrient deficiency like N, P, K in organic is low, high Al poisonous element, dryness (distribution and uneven rainfall fluctuation).

4. The Opportunity for Increasing Rice Production

Increasing rice production in South Kalimantan can be done in two ways, 1) adding more rice planting area, 2) increasing productivity. Addition of rice planting area can be done by two scenarios: 1) addition of new area, and 2) increasing plantation index (PI). Increasing rice productivity can still be done to think that there is still a gap between rice productivity with potential rice result and from research/assessment results that have been done before. Technology innovation (using high yielding varieties adaptive, fertilization, mechanization, cultivation technology, water management) will increases productivity/lessen the gap result.

4.1. Addition of Planting Area

Addition of paddy’s planting area in South Kalimantan can be done on fields that are not yet planted (rice) of 74,817 ha. Meanwhile increasing rice plantation index (PI) has a big opportunity, because the land that is planted two-times in a year just 9.14%, so it’s still possible to increase the plantation index mainly in irrigated rice fields, rain-fed rice field and tidal swampland. On rain-fed rice field required the manufacture of water storage, low storage, well, pumping, early mature rice so can be planted twice. On tidal swampland generally still using local varieties of rice can be planted rice two-time with planting patterns superior paddy-superior paddy or superior paddy-local paddy. Increasing two-times rice plantation index needed water infrastructure upgrade like the secondary canal, tertiary, making of floodgates, and pumping to control water in the rice field so it is not excessive or drying.

Increasing the production of upland rice in dry land can be done by adding a new planting area. Planted area of upland rice, corn and soybean reached 125.936 ha that planted on dry land. From the data of using the dryland field of Moor/farm/field has 345.000 ha still possible to expand the upland rice.

Rainfall in South Kalimantan is high enough, by observing the climate characteristics, land condition, the use of early plants age and matching planting pattern, plantation index in dry land can be increased by the pattern of upland rice-upland rice (two-times planting). The research’s result of water balance in dryland shows that few locations of dry land in South Kalimantan are possible to do two-time upland rice plantation, or one-time upland rice plantation with other plants with the pattern of upland rice-corn/peanuts/nuts [19]. Increasing plantation index requires the making of water storage, long storage, well to anticipate dryness in drought season.

4.2. Productivity Enhancement

The rice field productivity in South Kalimantan has just reached around 4.4 t/ha this is still below the national average, with technology innovation this can still be improved. In irrigated rice field/rainfed can applied jajar legowo super system (the use of seeds with quality like Inpari-30, Inpari-32, Inpari-33, Inpari-40), seeds treatment with agrimeth biological fertilizer, soil improvement with Biodestructor, using fertilizer based on Lowland Soil Test Kit, integrated pest control, the use of Bioprotector vegetable pesticides, the use of mechanization tillage, planting tool jarwo transplanter and harvesting tool Combine Harvester.

On tidal swampland with applying Integrated Crop Management using superior varieties and adaptive like Inpara 1, 2, 3, 4, 8, 9, the use of lime 500-1000 kg/ha, seed treatment with agrimeth, the
use of Biotara when tillage, balance fertilization based on Swampland Soil Test Kit, the use of mechanization. The success of rice field plantation determined by the accuracy of planting time→ this can be done by applying the right planting time with Integrated Planting Calendar. Research result the use of adaptive and tolerant varieties to iron poisoning can increase the productivity of Inpara-1, 2, 3, 4 that produce seeds with 4.13-5.55 t/ha compared to less adaptive varieties like Ciherang (1.59 t/ha) [20]. The use of ameliorant in tidal swampland Barito Kualaon Inpara-1 variety, straw compost application gave seed result of 5.02 t/ha and cow dung compost gave seed result of 4.94 t/ha higher than inorganic fertilizer 4.40 t/ha [21]. The distribution of straw compost can decrease the iron and sulfate content also increasing the rice production in tidal swampland [22].

In swampland with applying Integrated Crop Management, using superior varieties adaptive on swampland like Inpara-1, 2, 3, 8, 9, Inpara-17, 30, 32, 33, the seeds treatment with agrimeth, fertilization based on Lowland Soil Test Kit, jajar legowo plantation 2:1, the use of water pumping to anticipate dryness. If that swampland land can be manipulated with the right application of cultivation technology innovation, balance development and the right management with characteristics, quality and behaviour of swampland, can make swampland land as a productive agricultural land, sustainable and highly insightful [23]. The research result of the use of superior varieties in swampland area Hulu Sungai Utara district in South Kalimantan gave a result of high enough rice, Mekongga 6.4 t/ha and Cibogo 6.45 t/ha varieties [24]. Land preparation using rotary in shallow tidal land Balangan district in South Kalimantan can increase the rice productivity Batang Piaman varieties from 6.08 t/ha without tillage to 7.84 t/ha [25].

Upland rice planting in South Kalimantan generally still using local varieties with longer age around 140-155 days with low potential 2.5-4.0 t/ha. Upland rice in dry land can apply Largo Super innovation (upland rice) using superior varieties blast resistant (harvest age 110-123 days and potential result 5-6 t/ha) like Situ Patenggang, Inpago 8, Inpago 9, Inpago 10, and Inpago 11, for shade land using variety of Rinang-1, 2, seeds treatment with agrimeth, giving farmyard manure 1-2 t/ha, using mechanization tillage and plant tools. The increase of upland rice productivity can be done by observing the right time planting based on balance water analysis. The best upland rice planting in dryland Tanah Bumbu district South Kalimantan is different depends on rainfall and characteristics soil in saving water [26]. To increase the productivity of dryland, in addition to fertilization and liming is also important for increasing the productivity of acid soil, it can decrease the Al aluminium toxicity in plants that sensitive to high Al level [27]. Giving organic material can also increase the result of crop yields, lessen the use of fertilizer N, P, K and increases the efficiency [28, 29]. organic material can also stimulate the root growth and further caused P taken to get bigger [30].

5. Conclusion

The increase of rice production in South Kalimantan can be done with the addition of planting area and increasing productivity. Addition of rice planting area can be done by using the unplanted fields (74,817 ha), increases plantation index still low (PI 200 just 9.14%). Addition of upland rice planting area can be done on moor/dry filed that has an area of 345,669 ha, on the farming field that is not yet produced (185,539 ha), on tidal swampland, swampy land in drought season. Rice productivity in South Kalimantan still below the national average so that the productivity can still be enhanced with the application of technology innovation agroecosystem specific.

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