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The potential for developing sago-taro intercropping in South Sulawesi: a review

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Abstract. FAO predicts that by 2050, food production will need to increase by up to 60 percent, while at the same time there will be a scarcity of agricultural resources, especially land / land and water. Therefore, modernization of agriculture, exploiting the potential of marginal land resources and high adaptation-powered food crops such as sago (Metroxylon sagu Rottb) is an option. However, investment in sago cultivation is seen as inefficient because it is long-term so it is not attractive, especially for poor farmers. This review is aimed at discussing the potential of developing sago plants efficiently through the introduction of Japanese taro plant, satoimo (Colocasia esculenta var antiquorum) into sago plantations, forming the sago-taro intercropping system in South Sulawesi. It was found that the native sago vegetation area in South Sulawesi, namely in the Luwu Raya region, was socio-economically and culturally and ecologically potential for developing sago plants. It is also known that satoimo taro has a high economic potential, and is ecologically tolerant of shade so that it can be introduced into sago plantations — up to four or five years old — to form intercropping plantations. It can be concluded that intercropping of sago-taro, both of ecologically and socio-economically and culturally has high potential to be developed in South Sulawesi, especially in the Luwu Raya regions.

1. Introduction
Sago as a plant that has not been used optimally [1]. With deep concern about global food shortages, especially in 2050 as predicted by the FAO, sago is now being introduced as a reliable food source to overcome the world food crisis [2]. Some experts call it the bright and bright shining star of the 21st century, because it is a plant that has a strong sustainability nature with the ability to thrive in most soil conditions [3]. Sago plants can grow in a fairly wide range of places between 0-1150 meters above sea level, although generally only mostly found at an altitude of 0-10 / 60 m above mean sea level [4]. It can grow in poor hydrological or drainage conditions and acid soils, even with high salinity [5,6].
Dr. Isao Nagato (Japanese sago expert) also encouraged sago research because of his belief that sago will contribute very strongly in solving the problem of the world food crisis in the 21st century [7]. Even sago is declared as one of the most efficient carbohydrate-producing plants [6]. About 20 tons of carbohydrate / ha / year can be produced from sago stems [8]. Other experts report, 150-300 kg of dried sago starch per stem [2], and 90-700 kg of wet sago flour [9]. This is higher than the general productivity of other carbohydrate-producing crops. Along with the above issues, sago began to be widely discussed and targeted or object of research in various areas that have sago plants; no exception in South Sulawesi. In fact, cultivation has begun to be developed as an effort to meet the increasing demand for sago flour which is usually obtained from sago populations that grow wild in forest areas; and for conservation purposes. The Directorate of Plantations (2016) notes that in South Sulawesi there are 2,103 hectares of sago plants with an average production of 2,560 tons of dry sago flour per 2015. This is part of the nation's sago area of 146,817 hectares based on statistical data that continues to grow from year to year. In addition, there are also 20 thousand hectares owned by large private plantations, but the area has been stagnant since it existed in 2012.

South Sulawesi sago land is almost entirely located in the area of four regencies which are often called Luwu Raya (Luwu, North Luwu, East Luwu, and Palopo City), the area plans will continue to be expanded. Renacana which has become the commitment of the four district governments is not without challenges and severe obstacles due to the nature of the production of the sago plant itself, namely its relatively long harvest (around 8 to 14 years); meaning that it takes quite a long time to produce (return). To overcome this problem, the most likely alternative is to introduce other plants as intercropping to form a sago-taro intercropping system.

It is very convincing, that if lorang or inter-row between plants can be maintained from widening plant saplings, then enough to be planted and produce throughout the year [5]. The challenge then is how to choose intercropping that is ecologically appropriate so that it can produce well and be economically profitable. One of those suspected of having both requirements is the taro plant, especially Japanese taro.

Taro plants, for the people of South Sulawesi are well known because they grow scattered in all districts, even with a variety of varieties. However, it has not been attempted on an economic scale. The presence of new varieties, namely Japanese taro which is also more popular by the name of taro satoimo or "satoimo" (only) which is attractive to importers from Japan and has high productivity makes this plant including the existing varieties begin to 'glance' to be pursued on an economic scale. This review is raining to examine the potential for the development of sago plants that are integrated with (intercropping) sago-taro plants in the perspective of sustainable agriculture in South Sulawesi, particularly in the ‘Luwu Raya’ regions.

2. Social economic benefits of sago and taro

2.1. Sago benefits

About 20 tons of dry carbohydrate / ha / year can be produced from sago stems, and 240 tons of CO2 per hectare per year can be absorbed by sago vegetation [8]. Two main benefits of sago plants: (1) as a provider of food, and (2) as a control of environmental impacts through improved water management and absorption of carbon dioxide emissions. But now it has begun to develop towards another function, namely the provider of raw materials for industry. In Malaysia, the use of sago starch has increased, and has been used for glucose production.

Sago flour is an inexpensive alternative carbon source for an interesting fermentation process due to economic and geographical considerations. [10]. On Seram Island between five species of sago, tuni and sylvestre are the most potential species with an average production capacity of 566.05 kg and 560.68 kg
flour respectively, respectively [11]. In Sarawak—the world's largest exporter of sago—the production capacity of sago trees varies, from 2-5 t dry starch / ha in the wild and up to 25 t / ha on cultivated sago plants. Density of 1,480 trees / ha, allows an annual harvest of 125-140 stems / year. A well-treated crop can produce 175 kg of starch / stem, and give a total yield of 25 t [10]. Ishizaki reports that sago plants can produce carbohydrates with starch productivity of 10-15 tons / ha / yr, whereas starch from rice is only 3 tons / ha / yr; corn 5 tons / ha / yr, potatoes 2.5 tons / ha / yr; cassava 5-6 tons / ha / yr and sweetpotato 5.5 tons / ha / yr [8].

Elsewhere it was reported that sago could produce ethanol 12.2 kL / ha / yr (out of 20 tons of dried carbohydrates / ha / yr) higher than sugarcane 6.4 kL / ha / yr, corn 7.5 tons / ha / yr (2.5 times the harvest per year), and cassava which is only 3.8 kL / ha / yr [9]. Sago eggplant has also been used for making bread. The experimental results show that sago added to flour as a mixture of up to 50 percent (as much sago and flour) produces bread that is still in accordance with national standards except in terms of the level of development that is still lower (less developed) [12].

Sago waste has also been used; for the brick and gas industry. Sago pulp is used as a mixture of brick-making materials with quality products that meet SNI standards and are lightweight. Thus, it can reduce the burden of brick making costs and environmental impact [13]. Sago starch processing waste (SSPE) is an ideal biological resource (in the form of a substrate for the production of fermented hydrogen) that can be used as a substrate for fermentation reactions because of its relatively high organic content. In Malaysia, around 2.5 million tons of effluent are produced from the processing of sago starch and most of it is utilized (Yunus, Jahim, and Anuar 2014, and Hasyim et al. 2011). Sago waste can also be used for the production of enzymes, ethanol, glucose / fermentable sugar, and solid-substrate fermentation of sago ‘up’ [10].

2.2. Taro benefits
Taro is a nutrient-rich food source of carbohydrates. Taros’s tuber, in addition to containing carbohydrates, are also rich in collagen (a type of anti-aging) which is very popular among Japanese people because it is believed to cause youth and longevity [5]. It has a fairly high nutritional content, with a high protein content of 8.85% while a fat content of 0.56% lower than taro in general 1.64%, starch 63.51%, amylase 11.10%, amylopectin 52.91%, calories 92.30cal, carbohydrate 16.33g, calcium 9mg, phosphorus 5g and fiber content 16.18% [15].

Based on the RC ratio (RCR> 1), it is concluded that the satoimo taro is worth working for [16]. The productivity of satoimo taro with a proud yam harvest area in this area is 512 ha with an average production of 11,909.26 kgs / ha [17]. In South Sulawesi, based on several experiments, it can reach up to 40 tons / ha. With the prevailing market value, a hundred million rupiah or more can be achieved with an R / C ratio of 2 or more.

In international trade, for the time being the tuber yield of the satoimo taro plant is not widely known if it is consumed domestically. But it was requested in large quantities by Japanese importers. Japan requested Indonesia to average 2,500 tons of frozen per month, equivalent to seven to ten thousand tons of fresh tubers. Japanese imports averaged 45,000 tons of frozen per year, not much different from the state of imports recorded in one and a half decade before. In 2003 the total world import of satoimo to Japan was around 30 thousand tons fresh and 50 thousand tons frozen [18].

3. Development of sago and taro plants in South Sulawesi
Sago plants in Indonesia are dominant in the eastern region, which is around 95 percent, and only 4.1 percent in the western region. The total area of sago plants in Indonesia that grows wild is estimated at 2.25 million hectares, while only about 134 thousand hectares are cultivated [9]. But in 2015 the Directorate General of Plantations scanned a total data of 196,415 hectares [19]. In the same year the area
of people's sago plants in Sulawesi was 15,478 hectares. Developments in area and production of sago plants according to ownership are presented in Table 1, while developments according to plant conditions are presented in Table 2.

Meanwhile Japanese taro plants have also been developed in South Sulawesi. If in 2008 the area was only tens of hectares (in Bantaeng District), in 2019 hundreds of hectares had been planted in ten districts in South Sulawesi. Planting area of 178 hectares and with 72 groups of farmer will be completed through the grants of the South Sulawesi Provincial Government. The planting plan is shown in Table 3.

Table 1. Area and sago production according to ownership (Director General of Plantation, 2016)

| No | Provinces      | Smallholder plantation | State estate | Private estate | Total |
|----|----------------|------------------------|--------------|---------------|-------|
|    |                | ha         | ton        | ha         | ton    | ha    | ton |
| 1  | North Sulawesi |            |            |            |        |       |     |
| 2  | Gorontalo      |            |            |            |        |       |     |
| 3  | Central Sulawesi | 5.328     | 506       |            |        | 5.328 | 506 |
| 4  | South Sulawesi | 3.896     | 2.560     |            |        | 3.896 | 2.560 |
| 5  | West Sulawesi  | 1.682     | 661       |            |        | 1.682 | 661 |
| 6  | South East Sulawesi | 4.572 | 4.759 |            |        | 4.572 | 4.759 |
|    | Sulawesi       | 15.478    | 8.486     |            |        | 15.478 | 8.486 |
|    | INDONESIA      | 176.215   | 277.129   | 20.200     | 146.817 | 196.415 | 423946 |
|    | Sulawesi†      | 17.347    | 11.001    |            |        | 17.347 | 11.001 |
† estimated number 2017

Table 2. The area and sago production of Smallholder Plantations in South Sulawesi according to crop conditions (Director General of Plantations, 2016)

| No | Kabupaten/Kota | Luas Areal† | Producti on | Productivity | Total Farmer |
|----|----------------|-------------|-------------|--------------|--------------|
|    |                | IP          | PP          | ODP/RP       | ton          | ton/ha       |
| 1  | Luwu           | 194         | 935         | 256          | 1.385        | 888          | 950          | 3.133 |
| 2  | North Luwu     | 1.016       | 741         | 3            | 1.760        | 1.388        | 1.873        | 1.343 |
| 3  | East Luwu      | 31          | 74          | 28           | 133          | 168          | 2.270        | 188 |
| 4  | Palopo City    | 80          | 111         | 129          | 320          | 51           | 459          | 1.081 |
| 5  | Bone           | -           | 242         | 56           | 298          | 65           | 269          | 1.436 |
|    | Total          | 1.321       | 2.103       | 472          | 3.896        | 2.560        | 1.217        | 7.182 |
† IP=im immature pant, PP=productive plant, ODP/RP= old or dead or replanting plants
Table 3. Area of Japanese taro planting plan in South Sulawesi in 2019 (Department of Food Security, Food Crops and Horticulture, South Sulawesi Province, 2019)

| Regency/City | Area (Ha) | Farmer Group |
|--------------|-----------|--------------|
| Maros        | 27.49     | 4            |
| Gowa         | 25.11     | 6            |
| Takalar      | 16.75     | 10           |
| Jeneponto    | 19.75     | 3            |
| Bone         | 20.90     | 8            |
| Soppeng      | 15.60     | 11           |
| Wajo         | 3.25      | 6            |
| Luwu         | 19.25     | 7            |
| North Luwu   | 19.60     | 9            |
| East Luwu    | 10.30     | 8            |
| Total        | 178.00    | 72           |

4. The ecology of sago and taro plant

4.1. Climate and Hydrology

Areas that are suitable for sago are those that have a minimum temperature of 15 °C, a relative humidity (RH) of 90%, a radiation intensity of 900 j/cm²/day. Optimal rainfall is 2000 mm per year and evenly distributed throughout the year, less than two dry months and more than nine wet months [6]. In the highlands of Kalimantan, sago grows at altitudes above 1000 m above mean sea level [20]. In another part described, sago plants require adequate water availability during their growth. Water supply through rain is between 2,000 - 4,000 mm/year and is spread evenly throughout the year. Wet months between 4 - 9 months in a row, with dry months no more than 2 months in a row.

According to Schmidt and Ferguson's classification, areas suitable for sago development should have climate types A and B with a total rainfall of 2,500-3,500 mm and a number of rainy days of 142-209 rainy day per year. Sago plants are not very good if they are permanently inundated [5]. The optimum temperature is 24.5–29°C with a humidity of 40-60% and the highest is 90%. Sago plants like palm plants generally require high intensity and long irradiation. The distribution or distribution of the highest sago population is in the coordinates between 10 °S – 15 °N and 150 °E [5].

Sago trees thrive in swampy conditions where pneumatophores are not submerged, mineral nutrients and organic matter are high, and puddles are brown and slightly acidic. Sago trees can also grow in swampy areas near the sea, because they are tolerant of salinity. Sago trees have a tolerance of avoidance of Na+. Excess Na+ is stored in the root [6]. In areas that are often inundated or swamp the sago plant adaptation strategy extends many roots to the surface of the water. Research results and information from various sources state that inundation (not permanent) as high as <50 cm is the best [11].

4.2. Soil and Land

Sago plant is tolerant, can even grow well under very poor media conditions for most plants. In Sarawak, based on a 15-year study, it was shown that sago still grows well in peatlands. Although, which shows a good growth performance to a shallow depth of depth that is less than 1.5 meters thick. Moderate 2.5 meters more perform poorly; growth becomes stunted after four years of age. This study concludes, based on IRR criteria, it is not economical to cultivate sago on peatlands [2].
Sago can grow in various types of soil: (1) undeveloped soils, such as sulfaquents (sulfide soils), hidraquents (waterlogged), trapaquents (tropical climate), fluvaquents (alluvial), and psammaquents (sandy soils), and (2) developed soils such as trapaquents, troposaprists from peatlands, tropohemists and sulfihemists (sulfur soils and low pH), and thaptohistic fluvaquents [6]. This suitability level also depends on the variety. On Seram Island there are five species of sago palm, namely tuni, makanaro, silvestre, rotang, and mole. Tuni species are the most dominant vegetation which includes 43.3% of habitat [11]. The potential population of clumps on Seram Island is around 3.2 million clusters, of which around 1.5 million trunks. In Tebing Tinggi District, the sago cultivated are tuni, ihur and mole and are harvested differently by age, and through the sago development phase [21]. Based on observations of the character of sago growing, sago in Luwu is “ihur” kind. In the sago community there is a negative interspecific relationship with the Jaccard index <0.2. Among environmental conditions, sunlight intensity, cation exchange capacity (CEC), and calcium in water are the most important factors influence to the sago’s growth.

5. Sago and Taro Cultivations

5.1. Sago cultivation
Sago spacing is generally 8 m x 10 m, with a number of plants 8-10 plants per family at a year age interval. The fastest harvest is 8-10 years old. But all that is determined by plant varieties. The ideal plant spacing for three sago varieties (from Atmawidjaya, 1992) is: (i) Tunnel sago 8 mx 8 m or 9 mx 9 m, (2) Sago ihur 9 mx 9 m (3) molate sago 7 mx 7 m. The average harvest age is 12-15 years [21]. Indeed, plant spacing, like other cultivated plants, spacing is very crucial, because it determines productivity. Reportedly, on dense plantations the intensity of solar light near the sago groves is only around 12.33% (206.53 lux, open space 1,675.29 lux) [11]. Light becomes the most important environmental factor in the competition for growth environment resources related to plant spacing, in addition to other factors such as air, space, and underground components such as water, oxygen, and nutrients. Therefore, after planting the environment of the plant needs to be maintained harmony, especially the narrowing of the planting distance Hallway, especially if there are other uses such as planting productive inter-cropping.

Regarding varieties, the three varieties planted in Tebing Tinggi District which are also distributed in South Sulawesi, especially Luwu Raya, are described as follows: short spiny sago or tuni sago (M. *rumphii* Mart.), long thorny or ihur sago (*M. silvester* Mart), and un-spiny sago or sago molate (*M. sagu* Rottb). The three characteristics of the type of sago are as follows:
(a) Sago tuni. Plant height of 10-15 m, skin thickness of 2-3 cm, skin at the base is harder than skin in the middle or the top of the stem, the leaves are dark green, and the length of the frame (midrib) of leaves is about 5 -7 cm, spines length 1-4 cm.
(b) Sago ihur. Trees are relatively taller than other types of sago, between 12-16 m even reaching 20 m, leaf stalks around 4-6 m, leaves are dark green, have soft leaf bones and the ends swell downward, long spines 1-5 cm.
(c) Sago molate. Molate means female because it does not have thorns, plant height is 10-14 m, the position of the leaves blade is far apart, leaf sheets are about 2-5 cm long, leaf width is 7 cm, the flowers are reddish-brown compound. In Tebing Tinggi District, Riau, molate sago is planted in dry land, while tuni sago is in wetlands. Only a little sago is cultivated. In South Sulawesi, especially in the four regencies / cities in the Luwu region - commonly called Luwu Raya - most of the sago that grows, both cultivated and wild-growing, is Molat (*M. sagu Rottb*) [21].

For intercropping planting, of course, the spacing of planting plans so that the maintenance is more urgent. If sago groves are maintained and do not spread into the "empty" aisle, farmers are guaranteed not to experience income stagnation while waiting for the harvest. When viewed from the aspect of
agribusiness, the selection of types of farming with high economic value and clear market share is necessary [5].

6. Potential of Sago-Taro Intercropping Planting

The previous section discussed aspects of production and economic and market values. To answer whether sago-taro intercropping can be planted, several things and cultivation techniques are key to solving it. First, sago spacing must be planned properly. In this case it is proposed to be made as the distance of legowo rice planting with east-west orientation. Reflecting on legowo planting methods, with the principle of making efficient use of sunlight, it can be increased to 20-70 percent of production. Secondly, answer, is the satoimo taro plants tolerant of shade? For the answer, some research results are available.

Based on the results of the study, Satoimo is able to grow shaded (shade level) up to 70%. Production potential in sandy soils is higher (3.4 kg / m2) than in plots (2.04 kg / m2) [15]. In other, studies 20 varieties of taro have been tested. The results showed that in the shade of 25% there were 16 tolerant taro clones and 4 sensitive clones. At 50% shade there are 9 tolerant clones and 11 sensitive clones, while at 75% shade there are 7 tolerant clones and 13 sensitive clones. Increased leaf area and chlorophyll a and b levels of tolerant clones were higher than sensitive clones [22]. Specifically for satoimo taro or what is called Bali salak taro decreases in yields in line with the percent shade. With 25% of shade, production to 70.9%, 50% of shade to 64.0%, and 75% of production to 60.3%. Shade variations have also been made with tree stands. Jabon standing species produced the best yield of taro plant biomass (366.57 g / plant) compared to the sengon stand (266.15 g / plant), manglid (175.64 g / plant) and monoculture (182.98 g / plant). The intensity of light under jabon (Anthocephalus cadamba) stands in the agroforestry system was 41.17%. The type of stand significantly influences the growth and production of taro under the agroforestry system [23].

Satoimo taro plants, in the context of economic development in South Sulawesi, are strongly supported by the South Sulawesi Provincial Government. In 2019, at least 10 billion more are budgeted to support (subsidize) the planting of 178 hectares of satoimo taro. So, from an institutional standpoint this plant has the opportunity to be utilized in the context of intercropping testing. The development of sago also received support especially from the regional government of four regencies / cities of Luwu Raya.

7. Conclusion

The development of sago-taro intercropping planting is very potential in South Sulawesi both in terms of physical / environmental or ecological and socio-economic and culture. Innovation is needed to succeed the planting system.

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