Ecological study of Sago Palm (*Metroxylon sagu* Rott *ver molat* (Becc.)) in the natural habitat at Malili District East Luwu South Sulawesi

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Abstract. Sago palm (*Metroxylon sagu*), a tropical plant which mostly grows naturally and distributed in Eastern Part of Indonesia (including Wallacea Zone). However, currently the existing of sago palm is facing threats for food security in the future due to land conversion and life cycle of sago palm is a long term period (10 – 15 years). The objective of this research were: 1) Analyses of population structure of sago palm; 2) Regeneration potency of sago palm; and 3) describe habitat characteristic of sago palm. The research was conducted in April to August 2017 at Wewangriu Village Malili District. The circle plots (each 314 m²) were purposively established in a lowland sago palm area based on growth phase of sago palm. The pole and tree diameter were measured at breast height (1.30 m) above the trunk, but sapling and seedling were only counted the number of individuals. Moreover, environmental factors were measured directly at every center of plot. The result of research showed that population of sago palm in natural habitat was dominated by sapling with 226 individuals, then followed by seedling was 177 individuals. The regeneration potency of sago palm was categorized Fair based on relatif density and relatif frequency. Related to habitat characteristic or microclimate conditions, the temperature was hot and dry with ranged form 28.7°C to 29.5°C. Hydrology parameters such as water pH was about 6.0 to 7.9. Especially soil properties was dominated by silty clay and clay with slightly acid condition (soil pH 6.2 and 6.3). Maintaining the existence of sago palm, it is necessary to protect and preserve it in the natural habitat.

1. Introduction
Sago palm (*Metroxylon sagu* Rott) is a type of monocotyledone plant belongs to the Palmae and spreads in the hot humid tropics of Indonesia, especially eastern Indonesia (including the Wallacea region). This sago is also Hapaxanthic: the plant has terminal inflorescence, with a large number of fruit in each bole heralds the end of its life cycle, as well as has higher starch [1]. The starch stored in the bole is meant for the production of flowers and fruits. After the formation of fruits, the trunk decays, and one or more of the suckers from the cluster takes over [2]. Sago palm has a life cycle of up to 10-15 years, depending on the type and growing conditions, after that the tree will die [3].

Sago plants can grow in a variety of hydrological conditions, growing in swamp areas with fresh water or peat and along rivers, around water sources, or in swamp forests where salt levels are moderate and mineral soils are contain clay more than 70% and 30% organic matter. The sago palm is better growth on yellow-brown or black clay with high organic matter content [4]. Sago plants have high adaptability on marginal land which does not allow optimal growth for food and plantation crops [5]. Therefore, the
sago palm has function as a conservation plant. Sago has the ability to hold rainwater, this can be seen by the presence of springs that appear around the sago stands. Sago plants can also store water for a long time, characterized by standing water during the long dry season, and low erosion around the land where sago is grown. This plant is resistant to climate change, because sago roots have a hydrological function to regulate the arrangement of water sources in the soil, so that water quality is maintained and sago plants continue to produce, where other plants are difficult to grow [6]. Based on these conditions, sago continues to grow and regenerate normally. [3] state that with this condition, sago is able to cover the ground fastly, thereby reducing the impact of erosion.

South Sulawesi is one of the provinces in Indonesia where the distribution of sago palm is quite a lot with an area of 3,776 hectares [7], and is scattered in several regencies in South Sulawesi that are still overgrown with sago trees such as Selayar, Luwu, North Luwu, East Luwu, Bone, and Palopo. Sago palm area in East Luwu, is only scattered in several sub-districts such as Berau, Wotu, Malili and Wasuponda. Especially in Malili District, the area of sago in 2018 was around 70.50 Ha. However, in 2019, there was a decrease in the area only around 29.75 hectares [8]. The reduction of sago area has an impact on decreasing the population and potential of sago plants significantly. This is due to the clearing of sago forest which has been converted into settlements, public facilities and infrastructures, rice fields, excessive management and lack of attention from the government and local communities.

Sago palm grows in the form of a stretch of forest, but until now there has been no sago that has been cultivated intensively because sago is an annual or long-term crop, where the life cycle of sago is estimated to be 10-15 years before it can be harvested. Sago can grow in swampy areas or marginal soils where other carbohydrate producers are difficult to grow properly. The local community has just used sago starch as a local / traditional feed ingredient, such as dange, kapurung, bagea and others, as well as its leaves uses for roofing material.

Considering the function and importance of sago forest as a conservation plant as well as a food plant other than rice for future life, conservation efforts are needed in maintaining and maintaining the existence of the sago forest. Specifically, the description of habitat and potential for regeneration is used as the basis for the availability of tillers in their natural habitat that can support conservation activities. Therefore, it is necessary to study the ecology of sago plants in their natural habitat.

2. Research methods
The study site was conducted at the sago palm area in a Lowland of East Luwu Regency, South Sulawesi Indonesia. Luwu Timur Regency is located between 2°03'00" - 3°03'25" south latitude, 119°28'56" - 121°47'27" east longitude with area is 6,644 km². The average annual precipitation was 2151 mm. The highest monthly rainfall was 381 mm (recorded in March) and the lowest was 24 mm (in October). The air temperature was varying from 19°C to 36°C, and an average annual humidity was 80% [9]. The location for data collection in Wewangriu Village was conducted in April – August 2017 (figure 1).

A total of 4 circle plots were purposively established in a lowland sago palm area (5 m above sea level) at Wewangriu village. The plot, each 314 m² (plot diameter 20 m) in the area were certain placed based on growth phase of sago palm. The pole and tree diameter were measured at breast height (1.30 m) above the trunk with the diameter roll. However, sapling and seedling were only counted the number of individuals. Moreover, environmental factors such as temperature, humidity, and light intensity were measured directly at every center of plot. But, soil condition (soil depth, texture, OM, and pH), and hydrology parameters (DO, salinity and water pH), were collected the sampels and analyzed in the laboratory further.

The measurement data obtained in the field, will be analyzed to calculate the density (K), Relative Density (KR). The formula were used as follow [10]:

\[
Density (D) = \frac{\text{Total number of individu (each growth phase)}}{\text{Area plot}}
\]  

(1)
The population structure was analyzed based on number of individu or density by using formula from Odum [11]:

\[
Relative\ Density\ (RD) = \frac{\text{Density in each growth phase} \times 100\%}{\text{Total density}}
\]

The population structure was analyzed based on number of individu or density by using formula from Odum [11]:

(a) A pyramid with a broad base features the number of young individuals is greater than the old age Groups.

(b) A pyramid shape polygon with the number of young groups balance with the old age groups.

(c) A pyramid shape ptcher or jug with the number of young individual is smaller than the old groups.

The regeneration potential is analyzed in graphical form, where this graph is the result of calculating the number of individuals per growth rate, relative densities, and supported by regeneration status. Regeneration status based [12], is as follows:

1) Good if the number of seedlings > sapling > poles > trees.
2) Fair if number of seedlings > sapling > poles ≤ trees.
3) Poor if the species are able to live only on trees and seedlings.
4) There is no regeneration (None) if there are no species either at the pole, sapling or seedling levels.
5) Just regenerate (New) if there are no trees but only at the growth rate of poles, sapling and seedlings.

Figure 1. Map of Sago Palm distribution in Wewangriu Village.

3. Results and discussion

3.1. Population structure of Sago Palm

Population structure is a stratification of age in the population such as reproductive. Population structure belongs to density and distribution pattern, demografy of plant, age structure, the size of height and stem diameter [13, 14]. Population of sago palm includes growth phase of seedling, sapling, pole and tree in Wewangriu Village, is presented in the following table 1.
| Population Structure | Number of individu | Density (ind./ha) | Relative Density (%) |
|----------------------|-------------------|------------------|----------------------|
| Tree                 | 38                | 303              | 8.28                 |
| Pole                 | 18                | 143              | 3.92                 |
| Sapling              | 226               | 1799             | 49.24                |
| Seedling             | 177               | 1409             | 38.56                |
| **Total**            | **459**           | **3654**         | **100**              |

**Figure 2.** Population structure of sago palm.

Based on the calculation of the sago population structure in Wewangriu Village, Malili District, it was found that the number of sapling individuals was greater than the number of individuals for each growth level (tree, pole and seedling). The results show the density and relative density of sapling about 1799 individuals / Ha (49.24%), 1409 individual seedlings / Ha (38.56%), 143 individuals / Ha (3.92%), and density and relative density of tree belongs 303 individuals / Ha (8.82 %). The density and relative density of seedlings and sapling were higher than the growth rates of poles and trees, so it could be said that the population was growing. According to [15], in simple terms, the age structure of a population can be said to be a fairly developed population, characterized by a very large proportion of young individuals (sapling and seedling), which are also called young populations. The sago palm population in the study area has shown that the birthrate is greater than the mortality rate, this can be seen clearly by the large number of sapling and seedling than the number of trees.

A significant difference was seen in the growth rates of poles and trees. This shows that the density of the sago population structure, especially poles and trees, is experiencing disturbances. Based on observations in the field, the tree phase is mostly cut down before the flowers or fruit come out because the starch will be used for consumption. Meanwhile, the pole phase has the lowest density due to high mortality in the pole phase. This is thought to be due to the narrow land area so that there is competition between individual pole phases when growing into the tree phase, the impact is that the tree phase has a greater number than the pole phase.

In figure 2, it can be seen a pyramidal shape with a wide base in accordance with the population structure diagram by [11]. This indicates that the number of young individuals (sapling and seedlings) is greater than the old group (poles and trees). The existence of an age stage in the disrupted population structure is due to environmental factors that are not supportive for the growth and development of sago plants [16], as well as the population structure in a plant is influenced by factors of birthrate and morality rate. The number of individuals in the young sago group found can be said to have a good birthrate. According to [17], the rate of plant’s birthrate is influenced by the plant's ability to fertilize because with the growth of a fruit, individual regeneration will take place and result in plant maintaining its population over time. Meanwhile, the mortality factor due to human activity through logging on the growth rate of the old group.
Population structure also includes the size of stem diameter (dbh). Diameter class distribution of sago palm in the tree growth phase is shown in figure 3. The majority of the trees (90%) had diameter relatively large (dbh > 40 cm), only about 10% of them had diameter < 40 cm. In general, the tree individuals showed a decrease with declining tree diameter class. The diameter class of sago palm > 20 cm indicated that the tree are very reproductive phase. The tree diameters of sago palm with range > 40 cm have entered the ready to cut down, however local people prefer to cut down sago palm with a diameter > 60 cm because have more starches and the plant is old. The community maintain sago trees with a diameter between 40 and 60 as mother trees for further regeneration and preparation for harvesting later when the diameter enters the cutting period. The larger of diameter or basal area of sago palm, the greater level of controlling and using resources in its habitat.

3.2. Regeneration potency of Sago Palm

Plant regeneration is a natural phenomenon which is the process of replacing old plants by young plants. Sago plants that have a regeneration phase are those that have tillers at the seedling, weaning and pole levels. The success criteria for the regeneration process can be seen by calculating the number of growth rates and the highest density value in a growth structure. The regeneration potency of sago palm in Wewan griu Village, is performed in figure 4.
Based on figure 4, the most dominant density is found at the sapling with density value of 1977 ind./ha, then followed by seedling with density 1409 ind./ha. In the general, the growth phase of sago palm majority was found in sampling and seedling, but not all of them grew to tree level. This because competition for nutrients to grow, and is attacked by pests such as beetles. There is no silvicultural technique (thinning / pruning) and when the felling is finished, the cultivators of the sago do not clean the parts of the sago that suppress the saplings or seedling, thus they are difficult to grow. Tree density affects the existence of seedlings where there is less tree growth, the number of pole, sapling, and seedlings are also reduced, due to the growth process of the seedling comes from pneumetaphores (vegetative propagation) of the tree whose bases are old and have more fruit, compared to generative reproduction which derived from fruit to produce plants (seedlings).

The results study on the growth rate of sago form an inverted J curve. This shows that the regeneration conditions of the sago plants in SampeanWewangriu Village are fair category [12], where the number of individuals at the seedling level > sapling > poles > trees and the density values of seedlings and sapling are also higher than the density values of poles and trees. This is because some people still maintain and preserve for their sago palms and the habitat conditions which sago grow well. So that the regeneration process can take place because there is sufficient regeneration available, and can guarantee the sustainability of the sago plant in the future. According to [18], the horizontal structure of plants forming an inverted J curve will show a good secondary succession process over time. While, [19] stated that growth regeneration is an inverted J curve. This curve explained that the smaller the growth phase, the greater the number of individuals.

The local people of Wewangriu Village maintain the existence of their sago palms. For the community this is a source of staple food and some parts of the plant can be used, such as leaves, midribs, bark and pith. As well as, some of the people of Wewangriu Village refused their sago land to convert the land functions, such as rice fields, development of facilities and infrastructure. The sago plam grows on flat plains, flooded, expose to direct sunlight and contain the nutrients.

### 3.3. Habitat characteristics of Sago Palm
Measurement of environmental parameters in the Wewangriu Village obtained the results of soil characteristics, water characteristics and other environmental factors including temperature, humidity, and light intensity (table 2).

| Environmental Factor of Sago Palm Habitat | Sampling Plot |
|------------------------------------------|---------------|
|                                         | 1  | 2  | 3  | 4  |
| **Soil Characteristics**                 |    |    |    |    |
| a. Texture in Soil depth (cm)            |    |    |    |    |
| 0 - 15                                   | clay | silty clay | clay | silty clay |
| 15 - 30                                  | -   | silty clay | clay | silty loam |
| b. Organic Matter (%)                    | 15.0 | 12.5 | 14.0 | 12.5 |
| c. pH                                    | 6.2 | 6.3 | 6.3 | 6.3 |
| **Water Characteristics**                |    |    |    |    |
| a. Salinity (ppt)                        | 2.5 | 11.5 | 5.7 | 5.0 |
| b. DO                                    | 7.6 | 7.8 | 7.8 | 8.0 |
| c. pH                                    | 7.9 | 6.0 | 6.0 | 6.6 |
| **Other Environmental Factors**          |    |    |    |    |
| Temperature (°C)                         | 28.9 | 29.8 | 28.7 | 29.5 |
| Humidity (%)                             | 75.8 | 81.7 | 87.9 | 74.3 |
| Light Intensity (Lux)                    | 67.8 | 12.8 | 472.1 | 451.0 |
The soil characteristics measurement consisted of texture in soil depth (0 – 30 cm), organic matter, and pH. The soil texture in each plot varied from clay to silty loam at different soil depths, but the soil texture is dominated by clay. This shows that sago is more suitable for growing on clay soil. Especially in plot 1, the soil depth is very shallow, only reaching a depth of 15 cm so that the plot is inundated by water. On the other hand, organic matter contains 12.5 - 15%. The lowest organic matter was found in plots 2 and 4, while the highest organic matter values were in plot 1. This means that the organic matter content in the sago habitat is high category. This result is the same as the research conducted by [20], which states that soil contains more than 3% organic matter which resembles soil conditions in forest areas. This is because in the forest area there are quite a lot of organic material sources that come from forest plant litter. Sago palm grows on land with a relatively high content of organic matter, it is possible because the habitat for sago is generally found in lowlands, basin areas, hill valleys, on either side of rivers, or flat land near the coast. While the soil pH, in each plot almost have the same pH value 6.3, except plot 1 the pH is lower by 6.2, but does not show a significant difference. This shows that sago can grow in acidic pH conditions. Most of the sago habitat is swamps which are constantly inundated. If the inundation is longer, the habitat conditions become reduced, so that the soil pH will become acidic [20]. Meanwhile, [21] stated that sago plants grow well on muddy soils, groundwater is brown and reacts slightly acidic, and is very tolerant of pH 3.5-6.5.

Measurement of water characteristics includes salinity, DO and pH of water. The sago habitat in the research location is predominantly waterlogged (plots 2 and 3) due to its proximity to the main river, but at certain spots it is not inundated but conditions are still wet and humid (plots 1 and 4). Sago plants need adequate water, but permanent flooding can interfere with sago growth. Sago grows in swamp areas with fresh water or peat swamp areas and in areas along streams, around water sources, or in swamp forests where the salt content is not too high and mineral soils in freshwater swamps with clay content > 70%. and 30% organic matter, reproduce by producing tillers [22]. The salinity levels in each plot differed in the range 2.5 ppt - 11.5 ppt. The highest salinity was found in plot 2 (11.5 ppt), while the lowest salinity was found in plot 1 (2.5 ppt). These values are different with [20] study in Seram Island. The salinity of water in the sahu habitat on Seram Island is relatively fresh, including the type of habitat inundated with brackish water, the salinity is only 0.60 ppt. Meanwhile, DO and pH of water did not differ significantly in each plot. DO values have a range of 7.6 - 8.0, while the pH of water has the same value in 2 plots (plot 2 and plot 3), namely 6.0 which means slightly acidic. In plot 4 the water pH is 6.5, which means that it is slightly acidic to neutral. It's just plot 1 has a pH of water above the neutral number, which is 7.9 indicates that it is slightly alkaline. According to [23], environmental factors such as water pH greatly affect sago growth significantly in inundated and temporary areas. Water plays an important role for sago plants as a source of nutrients and a nutrient solvent.

Other environmental factors such as temperature, humidity, and light intensity are also affect the growth of the sago palm. At the research location found a temperature range of 28.7 - 29.8 ºC. Temperature is an environmental factor that affects plant growth and development. Temperature is positively correlated with solar radiation. The high and low temperature around the plant is determined by solar radiation, plant density, light distribution in the plant canopy, and soil moisture content [23, 24]. Humidity values above 70% (74.3 - 83.9%) which means very humid. The humidity in Wewangru Village, especially in the sago habitat, shows that the water vapor content under the sago stands is quite large. Relative air humidity is higher due to the slow movement of water vapor under the sago stands because it is covered by the sago canopy which grows very tightly. The results of this study are the same as the statements of [2] and [25] that sago palm needs humidity conditions > 70% to ensure better growth, while sago growth will be inhibited if the humidity is less than 40%. Likewise, research by [26] stated that sago plants grew well in the relative humidity conditions of about 83.34%. However, [22] states that the optimal humidity for growth is 60%, while the optimal temperature for sago growth ranges from 24.50–29 C and a minimum temperature of 15 C, with 90% relative humidity. However the light intensity has a value that varies in each plot. The highest light intensity is found in plot 3 (472.1 lux), while the lowest light intensity is shown by plot 2 (12.8 lux). The condition of light intensity is influenced by the canopy cover of sago palms, if
the high canopy cover is dominated by the growth rate of the trees and poles, then the light intensity is low. That is the reverse, if the canopy cover is low where the dominant saplings and seedlings or the number of trees are few, then the light intensity is high. This is in line with the argument of [20]. The low intensity of solar light entering the lower part of the sago grove or stand is caused by the resistance of the canopy formed from midrib and leaflets growing closer together.

4. Conclusions
- The population structure of sago palm in Wewangriu Village was found a pyramidal shape with a wide base. This indicates that the number of young individuals (sapling and seedlings) is greater than the old group (poles and trees). Population structure also includes the size of stem diameter, the tree individuals showed a decrease with declining tree diameter class. The diameter class of sago palm > 20 cm indicated that the tree are very reproductive phase.
- The regeneration potency of sago palm is fair category with form an inverted J curve, where the number of individuals at the seedling level> sapling> poles <trees and the density values of seedlings and sapling are also higher than the density values of poles and trees.
- The environmental factors such as soil characteristics, water characteristics and other environmental factors including temperature, humidity, and light intensity affect the growth of the sago palm.

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