

# Ethnobotanical role of sago in wetland biodiversity and resilience in the Riau Archipelago, Indonesia

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**Abstract.** Dewi TM, Sumarni W, Ridlo S, Marianti A. 2025. *Ethnobotanical role of sago in wetland biodiversity and resilience in the Riau Archipelago, Indonesia. Biodiversitas 26: 6232-6239.* Sago (*Metroxylon sagu*) is a tropical plant that plays an important role in wetland ecosystems and socio-economic resilience in Indonesia, particularly in the Riau Islands. This study aims to explore the role of sago ethnobotany in supporting biodiversity and ecosystem resilience in two locations, Musai (Lingga) and Alai (Karimun), and to identify how local wisdom-based sago management contributes to the conservation of the wetland ecosystem. The research approach employed was qualitative, semi-structured interviews (n = 40) with informants from various categories, including community leaders, traditional processors, farmers, and traditional leaders. Participatory observation was also conducted to explore local knowledge about sago management. The results showed that sago plays a dual role, serving as both a food source and economic commodity, and contributes to ecosystem management through management practices based on traditional ecological knowledge, such as crop rotation and selective pruning. Ethnobotanical index analysis shows that sago has the highest use value in the food category (UV = 1.00) and household economy/trade (UV = 0.63). This sago management also supports the achievement of Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) and SDG 15 (Life on Land), by increasing carbon sequestration capacity and preserving wetland ecosystems. Strengthening local sago-based management and integrating traditional practices into wetland policy frameworks are essential for achieving both livelihood security and biodiversity conservation in the Riau Archipelago.

**Keywords:** Biodiversity conservation, ethnobotany, *Metroxylon sagu*, wetland ecosystem

## INTRODUCTION

Sago (*Metroxylon sagu* Rottb.), a member of the Arecaceae family, in the order Arecales, and Calamoideae subfamily, is a tropical plant species indigenous to Southeast Asia, particularly Indonesia, Malaysia, and Papua New Guinea. Naturally thriving in lowland freshwater swamps and tropical rainforests, Indonesia is recognized as the country with the largest sago habitat area in the world, accounting for approximately 1.28 million hectares or 51.3% of the world's sago forest area (Metaragakusuma et al. 2017; Lim et al. 2019; Kadir et al. 2022). A large portion of these regions is considered natural sago ecosystems, where sago palms grow naturally with minimal or no human management and without reliance on external inputs (Sidiq et al. 2021). Recent spatial analyses indicate that Indonesia harbors approximately 5.54 million hectares of sago, with the provinces of Papua and West Papua accounting for more than 5.2 million hectares, while the remaining area is distributed across Sumatra, Kalimantan, Sulawesi, Maluku, and Java (Bintoro et al. 2018). Although sago is concentrated in eastern Indonesia (especially Papua and Maluku), its occurrence in Riau Islands, West Sumatra, and

Aceh indicates a broader westward distribution (Rahman et al. 2021). This extensive range confirms Indonesia as the global hotspot of sago biodiversity, emphasizing its ecological and cultural significance beyond Southeast Asia.

In the Riau Islands Province, sago cultivation is particularly widespread in Lingga and Karimun districts. According to the Central Statistics Agency (BPS) of Riau Archipelago (2017), three districts, Lingga, Karimun, and Natuna, serve as key centers of sago production, with a combined cultivated area of 5,841 hectares and a total production of 3,324 tons. Lingga leads with 3,349 hectares producing 2,610 tons, followed by Karimun (2,075 ha, 692 tons), and Natuna (252 ha, 10 tons). These data indicate that coastal and small island ecosystems in the Riau Archipelago possess strategic potential for sago development, both as a food resource and in supporting ecosystem-based conservation of wetlands. Coastal development, mangrove degradation, swamp drainage for habitations, and land conversion for plantations all put growing strain on the Riau Archipelago's wetland ecosystems, compromising their resilience. Because it jeopardizes both natural processes and local livelihoods, this degradation is very concerning and emphasizes the urgent need for conservation-oriented land management.

This regional situation is indicative of a global trend, in which over 35% of wetlands have disappeared since 1970, primarily due to drainage, coastal expansion, and changes in land use. This has led to a significant decline in biodiversity and a loss of ecosystem services (Fennessy et al. 2025).

Sago is widely recognized as a major carbohydrate-rich staple in regions such as Maluku, Papua, and Sulawesi (Sidiq et al. 2021). Beyond its fresh consumption, sago starch serves as the base for diverse processed foods, including *bagea*, sago pearls, cakes, noodles, biscuits, crackers, and *laksa* (Metaragakusuma et al. 2017). Nutritionally, it is characterized by high caloric and carbohydrate content, a dietary fiber level of 3.69-5.96%, and a low Glycemic Index (GI 28), qualifying it as a functional and health-promoting food (Maya et al. 2020). Thus, sago holds importance not only for food and nutrition security but also for sustainable development. From an ecological perspective, sago cultivation contributes to biodiversity conservation and the preservation of wetlands. The species plays a vital role in maintaining the functions of peatland and swamp ecosystems through its extensive root system, which supports carbon sequestration and soil stabilization, thereby mitigating erosion and land degradation (Tampubolon et al. 2021). Sago's significance as a nature-based remedy for climate change adaptation and mitigation is demonstrated by its connection to ecosystem services, which aligns with Indonesia's conservation policies and the Sustainable Development Goals (SDGs).

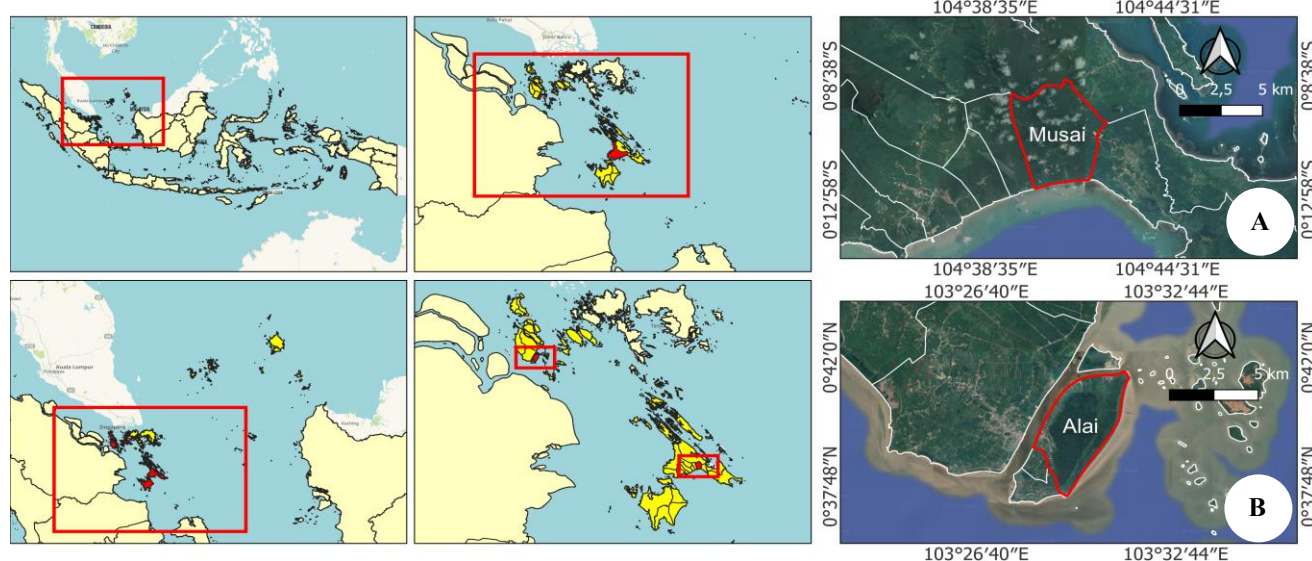
The ecological and ethnoecological dimensions of sago cultivation in traditional societies reflect a complex interplay between socio-environmental interactions. These relationships emphasize the importance of integrating traditional knowledge into conservation efforts. Ethnobotanical approaches that incorporate local ecological knowledge, such as indigenous classifications of sago varieties, harvest rotations, and ritual-based harvesting, are crucial for developing culturally sensitive, community-based biodiversity conservation strategies (Kadir et al.

2022). Among the Malay communities in the Riau Archipelago, particularly in Lingga and Karimun, sago remains a central component of both subsistence and cultural identity. Its use in daily food and ritual life illustrates the deep connection between the community and wetland ecosystems. Even though sago holds ecological and cultural significance, scientific research on ethnobotanical practices related to sago in this region is limited. Therefore, this study aims to explore the role of sago ethnobotany in promoting biodiversity and ecosystem resilience, and to identify how local wisdom-based sago management practices contribute to the conservation of wetland ecosystems in the Riau Archipelago, Indonesia.

## MATERIALS AND METHODS

### Study area

This research was conducted from February to July 2025 in Musai Village, Lingga Sub-district, Lingga District, and in Alai Urban Village, Ungar Sub-district, Karimun District, Riau Islands Province, Indonesia. Musai Village was selected as the study site because it is one of the areas with prominent natural sago potential in Lingga District, characterized by the dominance of sago vegetation growth on community lands and its sustainable utilization within the local food system, which contributes to the ecological resilience of coastal wetlands in the region (Manar et al. 2023). Meanwhile, Alai Urban Village was chosen because it is one of the villages with the highest sago production and serves as an active center for smallholder sago production in Karimun District. Geographically, Musai Village is located within the coordinate range of approximately 0°11'23.46" N and 104°41'36.14" E (Figure 1.A), while Alai Urban Village is situated within 0°39'45.90" N, 103°29'50.42" E (Figure 1.B), representing the spatial extent of each study area.



**Figure 1.** Map of research area. A. Musai Village, Lingga Sub-district, Lingga District, B. Alai Urban Village, Ungar Sub-district, Karimun District in Riau Islands Province, Indonesia

### Data collection

This study used a qualitative ethnobotanical approach to examine the cultural significance and local ecological knowledge of sago (*M. sagu*) among Malay communities in the Riau Archipelago, focusing on its role in supporting wetland biodiversity and resilience. Fieldwork was conducted in two purposively selected sites—Musai Village (Lingga District) and Alai Urban Village (Karimun District)—known for natural sago resources and community-based use. Informants were recruited through snowball sampling, prioritizing elders, traditional processors, and farmers recognized as key holders of sago knowledge.

A total of 40 informants participated, representing elders, traditional processors, farmers, and community leaders (Table 1), ensuring diverse perspectives on sago's cultural and ecological roles. Data were collected through semi-structured interviews and participant observation on harvesting, processing, and ritual significance, alongside observations of how sago use relates to wetland landscapes and local perceptions of ecological importance. Ethnobotanical documentation included photographs, participatory mapping, and narrative field notes to record the spatial distribution of sago groves. A supplementary literature review contextualized the findings within broader debates on wetland biodiversity, showing that sago supports wetland resilience in small-island ecosystems while also sustaining cultural and subsistence needs.

### Data analysis

The data were analyzed through thematic coding of interviews covering the use of sago in the context of food, cultural rituals, and ecosystems. In addition to qualitative analysis, an ethnobotanical index was used to assess the importance of sago, including Use Value Index (UVI), Fidelity Level (FL%), and Informant Agreement Ratio (IAR) (Saisor et al. 2021) as shown below:

The *Use Value Index (UVI)* is used to measure the importance of sago in daily life and in the cultural context of the community. This index is calculated based on the frequency of reports on sago utilization provided by informants in various categories, such as food, rituals, and ecology.

$$UVI = \frac{\sum_{i=1}^N U_i}{N}$$

Where  $U_i$  is the number of utilization reports provided by informants and  $N$  is the total number of informants.

*Informant Agreement Ratio (IAR)* is used to measure the level of consensus or agreement among informants regarding the use of sago in specific categories (e.g., food, rituals, and ecology). IAR provides an overview of the

extent to which informants agree on the role or use of sago in their culture.

$$IAR = \frac{(Nur - Nt)}{(Nur - 1)}$$

Where  $Nur$  is the sum of specific utilization reports from all informants, and  $Nt$  is the total number of reported utilizations.

*Fidelity Level (FL%)* is used to measure the level of consistency or sustainability of sago use in specific categories, such as its use in cultural rituals or ecology. FL% provides information on the extent to which sago use is accepted and used consistently by the community for the same purposes.

$$\% FL = \frac{Np}{Nt} \times 100$$

Where  $Np$  is the number of reports for specific uses in that category, and  $Nt$  is the total number of reports on sago utilization.

**Table 1.** Categories of informants, selection criteria, and roles in the study

Informant category	Amount	Selection criteria	Role in study
Elders	10	Acknowledged by the community as possessing knowledge of the biological history and customs of the sago	Ritual importance, traditional sago classification, and shared oral histories
Traditional processors	10	Actively involved in domestic starch extraction and processing	Supplied a thorough understanding of cultural customs, product diversity, and processing methods.
Farmers	10	At least five years of sago farming experience, with hands-on planting and harvesting	Described land management techniques, harvesting procedures, and agricultural techniques
Community leaders	10	Village chiefs, adat leaders, or esteemed individuals involved in land and resource decision-making	Provided viewpoints on community-based wetland conservation, cultural norms, and governance

## RESULTS AND DISCUSSION

Findings from Musai Village (Lingga District) and Alai Urban Village (Karimun District), Riau Islands, show that local communities possess strong traditional knowledge of sago harvesting and use aligned with wetland ecological conditions. They harvest selectively based on natural rotation and biological cues from the trees, and use sago for household needs as well as rituals and cultural practices that reinforce social cohesion and identity. These locally grounded practices support the conservation of coastal swamp ecosystems and strengthen environmental resilience without disrupting ecological balance. Overall, the ethnobotanical evidence highlights sago–culture–landscape interactions as an adaptive socio-ecological system that should be documented and maintained.

### Ethnobotanical knowledge and practices

The Malay communities of Musai (Lingga) and Alai (Karimun) possess rich ethnobotanical knowledge that reflects a close relationship with the sago ecosystem. Informants reported that the optimal harvesting age is 8–10 years, identified through biological cues such as yellowing leaves, stem enlargement, and reduced shoot growth. These local indicators align with morphological criteria recognized in ethnobotanical research for maximizing starch yield (Dimara et al. 2023; Iriansa and Mutmainnah 2024). A study by Kadir et al. (2022) identified five sago clusters in the Merauke region of Papua, based on local knowledge covering trunk size, presence of thorns, plant height, leaf shape and size, and trunk/leaf color, indicating the diversity of sago varieties known to the local community. This classification demonstrates adaptive strategies in sago management that promote ecological sustainability, as observed in both Musai and Alai, where spiny varieties are preferred for swamp habitats due to their resilience. Local people also classify sago into spiny and non-spiny varieties, guiding management strategies: spiny types are more resilient in swamp habitats, whereas non-spiny types are preferred for easier household processing (Figure 2).



**Figure 2.** Diversity of sago types based on the local knowledge of Malay people in Kepulauan Riau Province, Indonesia. A. Sago (thorny) in Musai Village, Lingga District. B. Sago (thorny) in Alai Urban Village, Karimun District.

This emic classification reflects adaptive strategies that support food production and ecological resilience. Field studies in Musai reported average stem diameters of 47.32 cm and starch yields of 238.66 kg per trunk harvested at the pre-flowering stage (Manar et al. 2023). To further assess sago (*M. sago*) use in Musai and Alai, this study quantified its importance using ethnobotanical indices—Use Value (UV), Fidelity Level (FL%), and Informant Agreement Ratio (IAR)—to describe the role and consistency of use across categories. Table 2 presents the index results.

Ethnobotanical indices (Table 2) indicate that sago (*M. sago*) has a consistently high food use value (UVI = 1.00), highlighting its importance for livelihoods in the Riau Archipelago. Moderate FL (68–84%) and IAR (0.72) across household, construction, and cultural uses reflect diverse yet shared community knowledge. In Musai and Alai, sago is mainly processed into wet or dry flour for local sale, wider distribution, and small-scale export, making it a key income source, while local consumption is largely complementary through traditional dishes (e.g., *lakse*, *lempeng sago*, *gobak*, *lendot*) that sustain culinary identity. This aligns with Trisia and Ehara (2021), who report that sago production is mostly smallholder-based and often valued more as a trade commodity than as a staple in many Indonesian regions.

Sago is important across Indonesia and Southeast Asia as both an economic commodity and a cultural symbol. In the Riau Archipelago, it supports livelihoods while reinforcing cultural identity; similarly, in Southeast Sulawesi, sago flour is often sold to wholesalers for distribution to other regions rather than consumed locally (Saediman et al. 2021). Its cultural value is evident in rituals and community practices, while ethnobotanical evidence shows it also supports wetland ecology through sustainable practices such as selective and rotational harvesting that maintain sago clump resilience and ecosystem productivity (Kadir et al. 2022). In Musai and Alai, sago is mainly processed into raw products for external markets, with local use more closely tied to cultural purposes. Overall, these dual economic and cultural roles highlight the need for holistic management to sustain ecological integrity and coastal community identity (Iriyori and Frank 2025).

**Table 2.** Ethnobotanical indices of sago (*Metroxylon sago*) among Malay communities in Musai (Lingga) and Alai (Karimun), Riau Archipelago, Indonesia

Category of use	Informants mentioning (n=40)	Fidelity level (FL, %)	Use Value Index (UVI)	Informant Agreement Ratio (IAR)
Food (staple and processed)	40	100.0	1.00	1.00
Ritual and ceremonies	12	30.0	0.30	0.30
Household economy/trade	25	62.5	0.63	0.63
Construction (thatch, tools)	10	25.0	0.25	0.25
Animal fodder	8	20.0	0.20	0.20

### Ecological benefit

The ecological function of sago palm (*M. sagu*) extends beyond providing food sources; it significantly contributes to climate change mitigation through its role in the carbon cycle and the maintenance of wetland ecosystems. Sago functions as a major carbon sink in swamp and peatland ecosystems. Research by Tano et al. (2023) suggests that sago plantations have high carbon sequestration potential, capable of absorbing approximately 23.29 tons of CO<sub>2</sub> per hectare during the flowering phase, surpassing other food crops, such as rice and corn, in their capacity for carbon storage. Irawan et al. (2024) further reinforce these findings, revealing that sago plants not only store carbon in their stem biomass but also in Soil Organic Carbon (SOC) stocks, with accumulation continuing to increase even after the plants are over a decade old. Thus, sago plays a strategic role in climate change mitigation while supporting the sustainability of peatland and swamp ecosystems.

In addition to its role in the carbon cycle, sago palm provides important hydrological benefits. The structure of its roots and clumps helps maintain soil moisture, reduce erosion, and support the hydrological functions of wetland ecosystems. Research by Botanri et al. (2024) in Ambon demonstrates that sago clump density and root characteristics contribute to spring discharge, with a coefficient of determination (R<sup>2</sup>) of 0.734, highlighting sago's potential as a bioindicator of water resources in wetland ecosystems. Meili et al. (2021) show that air humidity and rainfall positively correlate with spring discharge, while temperature and radiation negatively affect it, indicating that tree canopies, including those in sago ecosystems, play an essential role in slowing evaporation rates and stabilizing the microclimate. Additionally, Azhar et al. (2022) reveal that sago plays a crucial role in wetland rehabilitation, maintaining local hydrological functions by preserving groundwater quality. The fibrous root structure, equipped with aerenchyma tissue, stabilizes the soil, reduces erosion, and absorbs fluctuations in surface water, contributing to wetland conservation.

Sago also has a significant ecological contribution in maintaining biodiversity in the swamp and peat ecosystems. Dimara et al. (2023) emphasize that the physiological, anatomical, and phenological characteristics of sago are greatly influenced by biophysical variables, which in turn shape interactions and associations with various other species. Sago stands serve as microhabitats that support the existence of surrounding organisms. The dense canopy limits the intensity of light entering (<50%) and maintains high relative humidity (70-90%), thereby creating stable and conducive environmental conditions that support increased biodiversity in wetlands. Additionally, sago roots, equipped with aerenchyma tissue, are able to increase oxygenation in peat soil, thereby reducing methane (CH<sub>4</sub>) emissions. This process causes most of the CH<sub>4</sub> to be oxidized at the surface layer, stabilizing the decomposition of organic matter and thereby reducing carbon release into the atmosphere. Thus, sago ecosystems not only contribute to carbon sequestration but also play a crucial role in controlling other greenhouse gas

emissions, thereby strengthening the dual function of sago in climate change mitigation and biodiversity conservation (Wright et al. 2011).

Sago management practices based on local wisdom, as practiced by the Malay communities in Musai and Alai Urban Village, further enhance the resilience of wetland ecosystems in the Riau Islands. Selective harvesting, which involves cutting sago trunks during the pre-flowering phase, preserves the regeneration cycle of sago clumps and sustains the ecological functions of wetland ecosystems (Kadir et al. 2022; Manar et al. 2023). According to Dimara and Auri (2023), the success of sago regeneration is significantly influenced by land conditions, especially in wetlands with stable water availability throughout the year. Suitable land characteristics, such as an appropriate soil texture, low elevation, and ideal groundwater depth, not only maximize productivity but also support hydrological functions, enhance carbon absorption capacity, and preserve the habitats of wetland biota.

Crop rotation and buffer vegetation around sago stands help regulate hydrology, enhance carbon sequestration, and reduce erosion (Ehara and Toyoda 2018). Natural vegetation also functions as a sediment barrier and nutrient filter, improving water quality and lowering eutrophication risk. Thus, local wisdom-based sago management supports sustainable production while strengthening key ecological functions that enhance wetland resilience and conservation, aligning with SDG 13 (climate action) and SDG 15 (life on land). Consistent with Tano et al. (2023), sustainably managed tropical wetlands are important for carbon uptake, climate adaptation, and maintaining habitats for endemic and migratory species.

The results in Figure 3 confirm that selective harvesting and crop rotation practices not only support sago productivity but also maintain the continuity of young plant regeneration, thereby preserving the ecological function of wetlands. Irawan et al. (2024) demonstrate that the ideal groundwater depth (~6.8 cm above ground level) can support optimal stem diameter and biomass growth, highlighting the importance of stable hydrological conditions for sago to produce maximally without experiencing environmental stress. In line with this, Iriansa and Mutmainnah (2024) reported that the optimal sago harvest phase occurs at the *bulu bongko* and *ma'tanru jonga* stages, which have higher starch production potential than the previous growth phases. Morphometric factors, such as stem height, number of fronds, and canopy diameter, are closely related to starch productivity. Therefore, accurately determining the harvest phase is crucial for increasing yields and supporting the sustainability of sago production.

### Cultural values

The use of sago by the Malay communities in Musai Village (Lingga) and Alai Urban Village (Karimun) extends beyond its role as a food source, as it is also part of ethnobotanical practices that support biodiversity conservation and the resilience of wetland ecosystems in the Riau Islands. Sago is not only an economic commodity but also a crucial component in the interaction between the

community and its environment, with its utilization based on Traditional Ecological Knowledge (TEK) that contributes to sustainable ecosystem management (Ehara and Toyoda 2018; Suripatty et al. 2024). The interviews revealed that sago in both villages is processed into various traditional foods, such as *lakse*, *lendot*, *gobak*, *kue bangkit*, and *lempeng sago*, which strengthen the culinary identity of coastal communities. Sago also plays a significant role in various traditional rituals, including *kenduri* and *syukuran*, thereby integrating its presence into the community's religious and social practices. This confirms that sago is more than just a commodity; it is a medium of cultural expression that reinforces the values of togetherness, cooperation, and intergenerational transmission of traditions (Fetriyuna et al. 2024). Although not a staple food, the processing of sago into complementary foods and traditional culinary identities significantly contributes to community-based food security (Figure 4). Sago-based products, such as *papeda*, *bagea*, and *kapurung*, play a crucial role in strengthening local food availability and reducing dependence on imported foodstuffs (Dewayani et al. 2024).

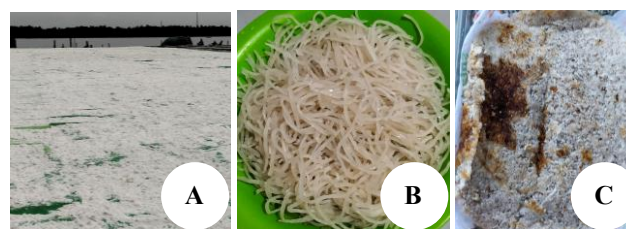
In addition to being a food source, sago has a deep symbolic meaning in the cultural identity of coastal communities, both in Papua and Maluku. According to Yono et al. (2025), the presence of sago in various traditional ceremonies is a crucial requirement for the completeness of these ceremonies, rendering it a cultural symbol that must be preserved due to its close connection to the social and cultural life of the Papuan people. In the Sentani society, folklore about sago depicts it not only as a food source but also as a symbol of sustainability and a connector of social relationships between community groups. Kadir et al. (2024) add that food, including sago, reflects the cultural character of a community. For example, in the culture of the Marind-Anim tribe in Papua, sago has a close relationship with myths and social rituals, where the birth of sago is believed to symbolize the birth of the world, thereby strengthening social bonds between

groups (Kimura and Sasaki 2022). Sago also plays a significant role in traditional rituals, such as feasts and celebrations, making it a vital symbol in preserving the community's culture and traditions (Sidiq et al. 2022). In traditional societies, such as the Marind Anim tribe, sago serves as a unifying force for social relations between groups, especially in funeral ceremonies, weddings, and conflict resolution. Sago is served in a way that shows affection, care, and friendship, where eating together is central to the communal culture that sustains their lives. Thus, sago plays two important roles: as an ecological resource and as a cultural symbol that strengthens social cohesion in society.

The integration of sago into local culinary traditions and practices has been shown to strengthen community solidarity, particularly through collective activities such as mutual assistance in harvesting and processing, which reinforces the role of sago in connecting cultural values, promoting social cohesion, and facilitating the sustainable use of local resources (Dahlani 2023). Sago management based on local wisdom and Traditional Ecological Knowledge (TEK) not only preserves traditional knowledge but also serves as a cultural adaptation strategy for communities facing socio-economic dynamics and climate change. This approach enables local communities to integrate traditional values with sustainable resource management practices, supporting ecosystem resilience and strengthening their cultural identity (Hilman et al. 2019; Permana 2025). Additionally, in the field of medicine, sago offers health benefits, primarily due to its lower glycemic index compared to rice, which plays a role in the prevention of diseases such as diabetes and hypertension (Girsang 2017). Despite a shift in consumption towards rice, sago remains a popular traditional food. The processing of sago, which requires more time and energy than rice, presents a challenge; however, sago-based products, such as *papeda* and sago cakes, have the potential to enhance local food security and reduce dependence on imported foods (Sidiq et al. 2022).



**Figure 3.** Field documentation of rotational and selective sago harvesting practices in wetland ecosystems in Riau Archipelago, Indonesia. A. Sago harvest in Musai Village, Lingga District. B. Sago harvest in Alai Urban Village, Karimun District



**Figure 4.** The processing of sago by the Malay communities involves several traditional stages, including the drying of wet sago (A) and its transformation into traditional foods such as "Lakse" (B) and "Lempeng sago" (C)

The use of sago is closely tied to socio-economic dimensions, making it a strategic adaptation in response to modernization and climate change. Swastiwi et al. (2023) state that sago-based food diversification plays a crucial role in enhancing household food security in coastal areas, while reducing dependence on imported rice. By making sago an alternative source of carbohydrates, coastal communities can increase the diversity of their food consumption and strengthen local food security. Research by Dahliani (2023) highlights that the use of local knowledge in sago management enhances community resilience to economic and environmental pressures, thereby helping to maintain the sustainability of sago plantations by creating environmentally friendly agricultural systems and reducing dependence on external inputs. Therefore, the use of sago not only serves to preserve wetland ecosystems but also strengthens the food security and social adaptability of coastal communities. In the villages of Musai and Alai, sago not only serves as a food source but also as a means of preserving cultural values, strengthening social networks, and implementing community sustainability strategies in the coastal areas of the Riau Islands. Socio-economically, sago has great potential in supporting local food security, reducing dependence on imported food, and strengthening the local economy through the sago farming sector. However, challenges include a lack of adequate policy support, lifestyle changes, and a shift to an industry-based economy, which hinder the sustainable development of the sago industry (Girsang 2017; Kimura and Sasaki 2022). Sago also plays a role in maintaining the sustainability of local ecosystems, with a smaller environmental impact than other crops such as oil palm, and contributes to the sustainability of natural resources and food security (Girsang 2017).

This study highlights the central role of sago (*M. sagu*) in supporting food security, biodiversity, and community resilience in the wetland ecosystems of the Riau Archipelago. This study reveals that sago is not only a source of food but also a cultural symbol that strengthens social cohesion through culinary traditions and rituals of coastal communities. Sago management practices based on local wisdom and Traditional Ecological Knowledge (TEK), such as crop rotation and selective pruning, have been proven to support the conservation of wetland ecosystems and enhance the ecological resilience of coastal areas. Additionally, sago plays a role in mitigating climate change by increasing carbon sequestration capacity and enhancing ecosystem functions. Socio-economically, sago has great potential to reduce dependence on imported food, increase food consumption diversity, and strengthen the local economy through the sago agriculture sector. However, the persistence of sago-based livelihoods is threatened by land-use conversion, declining intergenerational knowledge, and limited institutional support. Strengthening policy integration, promoting value-added processing, and revitalizing traditional sago management are essential to ensure long-term sustainability. Future studies should integrate spatial mapping, multi-seasonal surveys, and carbon or

biodiversity assessments to quantify sago's ecosystem service value and its contribution to climate adaptation. Collectively, these efforts will reinforce the multiple functions of sago, the preservation of wetland ecosystems, food security, livelihood resources, achievement of the Sustainable Development Goals (SDGs), and a keystone species in wetland conservation across the Riau Archipelago.

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## REFERENCES

- Azhar A, Asano K, Sugiura D, Kano-Nakata M, Ehara H. 2022. Waterlogged conditions influence the nitrogen, phosphorus, potassium, and sugar distribution in sago palm (*Metroxylon sagu* Rottb.) at seedling stages. *Plants (Basel)* 11 (5): 710. DOI: 10.3390/plants11050710.
- Bintoro MH, Nurulhaq MI, Pratama AJ, Ahmad F, Ayulia L. 2018. Growing area of sago palm and its environment. In: Ehara H, Toyoda Y, Johnson DV (eds). *Sago palm: Multiple contributions to food security and sustainable livelihoods*. Springer Nature, Singapore. Pp. 231-245.
- Botanri S, Uluputty MRA, Kamsurya M, Kamaruddin, Latuponu H, Habi M La, Djumat J La, Kaliky F. 2024. Utilization of sago plants (*Metroxylon* spp.) as a bioindicator of water springs. *Biodiversitas* 25 (4): 1682-1690. DOI: 10.13057/biodiv/d250438.
- Central Statistics Agency (BPS) of Riau Archipelago 2017. *Kabupaten Lingga, Karimun, dan Natuna dalam Angka*. Central Statistics Agency (BPS), Riau Archipelago. [Indonesian]
- Dahliani L. 2023. Local wisdom sago plantations' assistance in sustainable sago farming: Innovation clusters as a sustainable sago development model (2000-2023). *Jurnal Agri Rinjani* 3 (1): 50-64. DOI: 10.53952/jar.v3i2.282.
- Dewayani W, Mahendradatta M, Laga A. 2024. Post-harvest handling of sago and the sustainability of the processed results. *BIO Web Conf* 96: 02001. DOI: 10.1051/bioconf/20249602001.
- Dimara PA, Auri A. 2023. Effect of landform on the distribution of *Metroxylon sagu* habitat in Yapen Islands, Papua Province, Indonesia. *Jurnal Sylva Lestari* 11 (1): 79-97. DOI: 10.23960/jslv11i1.633.
- Dimara PA, Purwanto RH, Auri A, Angrianto R, Mofu WY. 2023. Production potential of sago forests in different habitat types in Sentani watershed, Papua, Indonesia. *Biodiversitas* 24 (7): 3924-3931. DOI: 10.13057/biodiv/d240731.
- Ehara H, Toyoda Y. 2018. *Sago Palm: Multiple Contributions to Food Security and Sustainable Livelihoods*. Springer Nature, Singapore. DOI: 10.1007/978-981-10-5269-9.
- Fennessy S, Hilton GM, Job N. 2025. *Global Wetland Outlook 2025: Valuing, Conserving, Restoring and Financing Wetlands*. Secretariat of the Convention on Wetlands, Gland, Switzerland.
- Fetriyuna F, Letsoin SMA, Jati IRAP, Purwestri RC. 2024. Potential of underutilized sago for bioenergy uses. *Intl J Adv Sci Eng Inf Technol* 14 (1): 144-150. DOI: 10.18517/ijaseit.14.1.19202.
- Girsang W. 2017. Sago food product development for food security in small islands, Maluku, Indonesia. *Intl J Sci Eng Res* 8 (5): 704-712. DOI: 10.14299/ijser.2017.05.019.
- Hilman I, Hendriawan N, Sunaedi N. 2019. Culture of local wisdom of Kampung Kuta community in facing climate changes in Ciamis Regency, West Java. *IOP Conf Ser: Earth Environ Sci* 338: 012006. DOI: 10.1088/1755-1315/338/1/012006.
- Irawan AF, Kusmiyati F, Suwarno M, Purbayanti ED, Rahim GA, Asmono D. 2024. Evaluating sago palm (*Metroxylon sagu*) cultivation practices: Aspects of groundwater level and reduction of starch during harvest

- transportation. *Intl J Agric Biol* 32 (3): 261-270. DOI: 10.17957/IJAB/15.2200.
- Iriansa, Mutmainnah. 2024. Morphological, morphometric, and distribution pattern characteristics of optimal harvest phase sago in forest area based on drone imagery. *Indones J Soc Environ Issues* 5 (3): 318-334. DOI: 10.47540/ijsei.v5i3.1720.
- Iriyori IE, Frank SAK. 2025. *Kuru*: The meaning of sago for the Warembori Tribe's life in Mamberamo Raya Papua. *Equilibration: Univers J Acad Appl Sci* 1 (1): 17-24.
- Kadir A, Suharno, Reawaruw Y, Komari, Mahuze A. 2022. Ethnobotanical knowledge of the Marind-Anim Tribe in utilizing sago (*Metroxylon sago*) in Merauke, Papua, Indonesia. *Biodiversitas* 23 (1): 264-272. DOI: 10.13057/biodiv/d230132.
- Kadir A, Suharno, Reawaruw YI, Ali A, Putra MFP. 2024. Sago Sep: traditional food sources in eastern Indonesia and their potential as alternative foods for athletes. *Retos* 61: 544-551. DOI: 10.47197/retos.v61.109661.
- Kimura Y, Sasaki R. 2022. Staple food shift in Papua, Indonesia: A discussion based on the study of diabetic patients and the cultural significance of sago palm. *Sago Palm* 29 (2): 53-62. DOI: 10.57418/sagopalm.29.2\_53.
- Lim LWK, Chung HH, Hussain H, Bujang K. 2019. Sago palm (*Metroxylon sago* Rottb.): Now and beyond. *Pertanika J Trop Agric Sci* 42 (2): 435-451.
- Manar PA, Zuhud EAM, Andarwulan N, Bintoro MH. 2023. Morphological characteristics and potential of sago (*Metroxylon* spp.) in Lingga Regency, Riau Islands, Indonesia. *Jurnal Manajemen Hutan Tropika* 29 (1): 11-21. DOI: 10.7226/jtfn.29.1.11.
- Maya S, Sulaeman A, Sinaga T. 2020. Alternative snack for diabetic patients from sago (*Metroxylon* sp.) starch and tempe. *Jurnal Gizi dan Pangan* 15 (1): 27-36. DOI: 10.25182/jgp.2020.15.1.27-36.
- Meili N, Manoli G, Burlando P, Carmeliet J, Chow WTL, Coutts AM, Roth M, Velasco E, Vivoni ER, Fatichi S. 2021. Tree effects on urban microclimate: Diurnal, seasonal, and climatic temperature differences explained by separating radiation, evapotranspiration, and roughness effects. *Urban For Urban Green* 58: 126970. DOI: 10.1016/j.ufug.2020.126970.
- Metaragakusuma AP, Osozawa K, Hu B. 2017. The current status of sago production in South Sulawesi: Its market and challenge as a new food-industry source. *Intl J Sustain Future Human Secur* 5 (1): 32-46. DOI: 10.24910/jsustain/5.1/3246.
- Permana DY, Imamulhadi I, Idris, Mariana M. 2025. Integrating indigenous wisdom and village authority in environmental protection: A case study of Indonesia. *JALREV* 7 (2): 359-389. DOI: 10.33756/jlr.v7i2.29582.
- Rahman HBA, Bintoro MH, Supijatno S. 2021. Variation in leaf morphology of sago trees (*Metroxylon sago*) in South Borneo Province, Indonesia. *J Trop Crop Sci* 8 (2): 51-59. DOI: 10.29244/jtcs.8.02.51-59.
- Saediman H, Helviani H, Said LR, Sarinah S, Taridala SAA, Alwi LO, Rianse IS. 2021. Market structure of sago starch in Southeast Sulawesi, Indonesia. *WSEAS Transactions Business Econ* 18: 628-635. DOI: 10.37394/23207.2021.18.62.
- Saisor N, Prathepha P, Saensouk S. 2021. Ethnobotanical study and utilization of plants in Khok Nong Phok Forest, Kosum Phisai District, northeastern Thailand. *Biodiversitas* 22 (10): 4336-4348. DOI: 10.13057/biodiv/d221026.
- Sidiq FF, Coles D, Hubbard C, Clark B, Frewer LJ. 2021. Sago and the indigenous peoples of Papua, Indonesia: A review. *J Agric Appl Biol* 2 (2): 138-149. DOI: 10.11594/jaab.02.02.08.
- Sidiq FF, Coles D, Hubbard C, Clark B, Frewer LJ. 2022. Factors influencing consumption of traditional diets: Stakeholder views regarding sago consumption among the indigenous peoples of West Papua. *Agric Food Secur* 11 (1): 51. DOI: 10.1186/s40066-022-00390-5.
- Suripatty BA, Lewerissa E, Utomo PM, Lekitoo K, Noya J, Komendi Y, Manusawai J, Murdjoko A, Ura R, Rahmila YI, Parera E, Suli AAT. 2024. Varietal diversity and nutritional analysis of sago starch (*Metroxylon sago* Rottb.) in Kainui, Papua. *Intl J Design Nat Ecodyn* 19 (1): 147-154. DOI: 10.18280/ijdne.190117.
- Swastiwi AW, Febriyandi YS, Simbolon G. 2023. Maritime community food security: Case study of Meranti sago. *IOP Conf Ser: Earth Environ Sci* 1148 (1): 012011. DOI: 10.1088/1755-1315/1148/1/012011.
- Tampubolon AP, Turjaman M, Osaki M. 2021. Sago palm practice as natural AeroHydro culture. In: Osaki M, Tsuji N, Foad N, Rieley J (eds). *Tropical Peatland Eco-Management*. Springer Nature, Singapore. DOI: 10.1007/978-981-33-4654-3\_12.
- Tano RL, Raga-as ML, Saladar RL, Rola JII. 2023. Carbon sequestration potential of sago (*Metroxylon sago* Rottb.) plantation in Aklan State University, Banga, Aklan, Philippines. *J Biol Environ Sci* 22 (6): 101-108.
- Trisia MA, Ehara H. 2021. Commercialization of sago starch in Indonesia: Production, consumption and international trading. *Sago Palm* 29: 39-47.
- Wright EL, Black CR, Cheesman AW, Drage T, Large D, Turner BL, Sjögersten S. 2011. Contribution of subsurface peat to CO<sub>2</sub> and CH<sub>4</sub> fluxes in a neotropical peatland. *Glob Change Biol* 17 (9): 2867-2881. DOI: 10.1111/j.1365-2486.2011.02448.x.
- Yono S, Siswanto, Murdowo DA, Satiyoko YA. 2025. The Sago Plant in the Folklore of Papua and Its Potential for Creative Economic Development. *Atlantis Press SARL, Paris*. DOI: 10.2991/978-2-38476-394-8\_41.