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Sustainable sago plantations based on local wisdom in Indragiri Hilir Regency, Riau Province, Indonesia

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ABSTRACT: The development of tidal swamp land for sago plantations is a potential source of food for future generations. Sago is a native plant of Indonesia that has the highest carbohydrate content and can grow properly in flooded conditions. Through management considering local wisdom, sago plantations in Indonesia have survived for several years despite limited infrastructure, global climate change, lack of government policy support, and changes in community food preferences for rice and wheat. Therefore, this study aimed to determine the effect of management practices on the sustainability of sago plantations and analyze local wisdom values. The research was conducted from November 2023 to January 2024 in Indragiri Hilir Regency, Riau Province, because sago has been planted in this area for hundreds of years with locally wise management. A mixed method with explanatory sequential design was employed, namely a combination of quantitative analysis with the Structural Equation Modeling - Partial Least Squares (SEM-PLS) and qualitative analysis with the Miles-Huberman approach. The results showed that local wisdom was in the form of local knowledge, socio-spiritual values, and community norms. This local wisdom existed from the pre-planting to the marketing of the harvest. Furthermore, local knowledge as well as social values and norms had a significant effect on sustainability, but current harvesting and water management practices are not optimal. The results suggested that practices in water management and harvesting required innovation to be more effective and increase plantation productivity through collaboration with science-based knowledge and formal regulatory systems.
Keywords: local knowledge; scientific local wisdom; sago sustainability.

Plantações sustentáveis de sagu baseadas na sabedoria local na Regência de Indragiri Hilir, província de Riau, Indonésia

ABSTRACT: O desenvolvimento de terras pantanosas de maré para plantações de sagu é uma fonte potencial de alimento para as gerações futuras. O sagu é uma planta nativa da Indonésia que possui o maior teor de carboidratos e pode crescer adequadamente em condições de inundação. Através de um manejo que considera a sabedoria local, as plantações de sagu na Indonésia sobreviveram por vários anos, apesar da infraestrutura limitada, das mudanças climáticas globais, da falta de apoio das políticas governamentais e das mudanças nas preferências alimentares da comunidade, que passaram a preferir arroz e trigo. Portanto, este estudo teve como objetivo determinar o efeito das práticas de manejo sobre a sustentabilidade das plantações de sagu e analisar os valores da sabedoria local. A pesquisa foi conduzida de novembro de 2023 a janeiro de 2024 na Regência de Indragiri Hilir, Província de Riau, pois o sagu tem sido plantado nesta área há centenas de anos, com manejo localmente sábio. Foi empregado um método misto, com delineamento explicativo sequencial, ou seja, uma combinação de análise quantitativa, por meio da Modelagem de Equações Estruturais - Mínimos Quadrados Parciais (SEM-PLS), e de análise qualitativa, por meio da abordagem Miles-Huberman. Os resultados mostraram que a sabedoria local se manifestava em conhecimento local, valores socioespirituais e normas comunitárias. Essa sabedoria local existia desde o pré-plantio até a comercialização da colheita. Além disso, o conhecimento local, bem como os valores e normas sociais, tiveram um impacto significativo na sustentabilidade, mas as práticas atuais de coleta e gestão da água não são ideais. Os resultados sugeriram que as práticas de gestão da água e de coleta exigem inovação para serem mais eficazes e aumentar a produtividade das plantações, por meio da colaboração com o conhecimento científico e com sistemas regulatórios formais.
Palavras-chave: conhecimento local; sabedoria científica local; sustentabilidade do sagu.

1. INTRODUCTION

The rapid growth of the world's population is estimated to reach 9.2 billion by 2025 (FAO, 2017), facing challenges in providing food due to the threat of extreme climate change, drought, floods, as well as pest and disease attacks (HORN et al., 2022). Despite these challenges, sago plantations have shown significant potential as a future food source due to the high starch content (EHARA, 2009; LIM et al., 2021). This plant is resistant to climate change (Trisia et al., 2016; Wulan, 2018), specifically in coastal swamp areas (Syahza et al., 2020) or peatlands (MING et al., 2018). Another advantage is the ability to improve the hydrological cycle and carbon storage capacity in wetlands and peatlands (BINTORO et al., 2018). Furthermore, sago plays an important role in the socio-cultural life of the surrounding community, showing a close relation to customary law (NOPIANSYAH et al., 2016; TEHUPEIORY, 2021).

Despite the significant potential of sago plantations, Indonesia faces the challenges of low productivity, limited infrastructure, and a lack of government support. These plantations are in isolated coastal swamp areas, which limit inclusion in government programs. Despite having the largest growing area in the world (Konuma, 2018), the productivity of sago starch in Indonesia is still low, accounting for 10-15 tons/ha/year (AHMAD, 2014). This value is lower compared to Sarawak, Malaysia, which reaches 23 tons/ha/year (YAMAMOTO et al., 2003).

In Indonesia, Riau Province is the largest producer of sago starch, with 297,380 tons (73.97%) (DIRECTORATE GENERAL OF INDONESIAN ESTATE CROP, 2024). The flour production from this area meets the needs of local and export markets. This plant has been planted by the community for several years as a source of staple food and a commodity that drives the economy. The use of sago as a raw material for flour and several industrial applications presents a promising market opportunity. However, the typical environmental conditions for sago growth, particularly tidal swamp areas, require adaptation by the community. This process of interaction with the environment produces practical knowledge passed down from one generation to another, forming local wisdom.

Local wisdom of sago farmers is in the form of comprehensive knowledge and social values, which include area determination, variety selection, water management, and an environmentally friendly harvesting system. Additionally, the marketing system is economically oriented, containing elements of mutual assistance and trust. These values are held by the community in managing natural resources, showing successful maintenance of ecosystem balance as well as economic and social benefits (FLOOD et al., 2022).

Management practices with local wisdom methods specific to the area, culture, and dynamics have been proven to increase business results (HASYIM; MUDA, 2019). This method is considered more effective due to the acceptance by the community (KAHFI et al., 2021). Dynamic local wisdom allows for continued advancement and collaboration with scientific knowledge that can make agricultural development more sustainable (AKSOY, 2020; FLOOD et al., 2022).

Although various studies of sago have been conducted on aspects of cultivation (Nabeya et al., 2015; Bintoro et al., 2018; Girsang, 2018; Lim et al., 2021), agro-industry development, and marketing (Surni et al., 2020; Saediman et al., 2021; Timisela et al., 2021), the existence of local wisdom has not been investigated. Therefore, this study aimed to determine how management practices influence sustainability and analyze local wisdom values in sago plantations.

2. METHODS

This study was conducted in the Sago plantations center in Indragiri Hilir Regency, Gaung, Gaung Anak Serka, Pelangiran, and Mandah Sub-districts from November 2023 to January 2024. The experiment was performed using a mixed method with an explanatory sequential design. This included collection as well as analysis of quantitative and qualitative data (CRESWELL, 2018). The quantitative method was used to determine the effect of management practices on the sustainability of sago plantations. Meanwhile, the qualitative method was used to determine local wisdom forms and values in sago plantations management.

Quantitative analysis was conducted using the Structural Equation Model (SEM) with the Partial Least Squares (PLS) method, with the sample size determined based on (HAIR et al., 2017). Meanwhile, the number of good samples was a minimum of 120. In this study, the number of samples used was 280, comprising 15% of the sago farmer population in Indragiri Hilir. Sampling was carried out using simple random sampling. Furthermore, data collection was performed by direct interviews using a questionnaire with a Likert scale, with variables and indicators shown in Table 1.

Table 1. Operational definition of variables.
Tabela 1. Definição operacional das variáveis.

Variable	Indicator
Farmer characteristics (FC)	- Age (FC1), education (FC2), experience (FC3), motivation for sago farming (FC4)
Agroecology (AE)	- Effect of salt water (AE1), peat depth (AE2), tidal influence (AE3)
Water management (WM)	- Completeness of ditch (WM1), ditch washing (WM2), ditch quality (WM3)
Cultivation practices (CP)	- Nursery method (CP1), post-harvest replanting (CP2), pest and disease control (CP3), clump thinning (CP4), leaf sheath pruning (CP5), weed cleaning (CP6)
Harvesting practice (HP)	- Harvesting time (HP1), existence of alleys in the garden (HP2), logs soaking (HP3), harvesting method (HP4), logs transportation system (HP5)
Social culture (SC)	- Mutual trust (SC1), kinship (SC2), spirit of mutual help (SC3), spirit of mutual cooperation (SC4), Belief in myths (SC5)
Supporting institutions (SI)	- Formal farmer groups (SI1), informal farmer groups (SI2), informal conflict resolution (SI3), government policy (SI4)
Sustainable plantations (SP)	- Damage by salt water (SP1), pest and disease attacks (SP2), land fires (SP3), productivity (SP4), contribution to family income (SP5), price stability (SP6), market access (SP7), conflict intensity (SP8), mutual cooperation intensity (SP9), member participation in groups (SP10)

The SEM PLS model test includes testing the measurement model (outer model) and testing the structural model (inner model). The types of tests and criteria used are presented in Table 2. The qualitative method was conducted through in-depth interviews with the community leaders, village heads, traditional leaders, plantation service, farmers, factory owners, and traders, as shown in Table 3. Subsequently, the data obtained were analyzed using the MILES et al. (2014) rules, consisting of data collection, presentation, condensation, and conclusion. The analysis is performed using an iterative method, showing that the four stages are not linear but are interrelated and can be repeated.

Table 2. Tests performed on the model.
Tabela 2. Testes realizados no modelo.

Criteria	Description	Reference
1. Measurement model test	- Loading factor with a threshold of ≥ 0.7	(HAIR et al., 2017)
2. Reliability	- Conducted using Cronbach's alpha (CA) with a threshold of ≥ 0.6, and composite reliability (CR) indicators with a threshold of ≥ 0.7;	(HAIR et al., 2017)
3. Convergent validity	- AVE with a threshold of ≥ 0.5	(HAIR et al., 2017)
4. Discriminant validity	- Fornell Larcker - Cross loading.	(HAIR et al., 2017)
5. R square	- Values of 0.67, 0.33, and 0.19 are considered strong, moderate, and weak, respectively.	(CHIN, 1998)

Table 3. List of in-depth interview participants
Tabela 3. Lista de participantes da entrevista em profundidade

No	Respondents	Objective
1	Riau Malay Customary Institution (LAMR) of Indragiri Hilir Regency	- Knowing the history of sago plantations and the values of sago for the Malay ethnic community.
2	Plantations Service of Indragiri Hilir Regency	- Knowing the problems in sago plantations and related policies.
3	Village Head	- Knowing the dynamics of society in managing sago plantations and their use.
4	Customary or community leader	- Knowing the values and philosophies in practices related to garden management, sago use, and existing rules or prohibitions.
5	Sago farmer	- Know the management practices of sago plantations.
6	Factory owner	- Understand the sago logs trading system.
7	Trader collector sago logs	- Understand the sago logs trading system.
8	Trader collector sago flour	- Understand the sago starch marketing network and its trading system.

3. RESULTS

3.1. Analysis of the effect of management on the sustainability of sago plantations, outer loading factor

The reliability indicator is considered high when the loading factor value is greater than 0.70 for the intended construct. Therefore, the construct value with a loading factor smaller than 0.7 should be eliminated. The results of the loading factor measurement after elimination are shown in Figure 1.

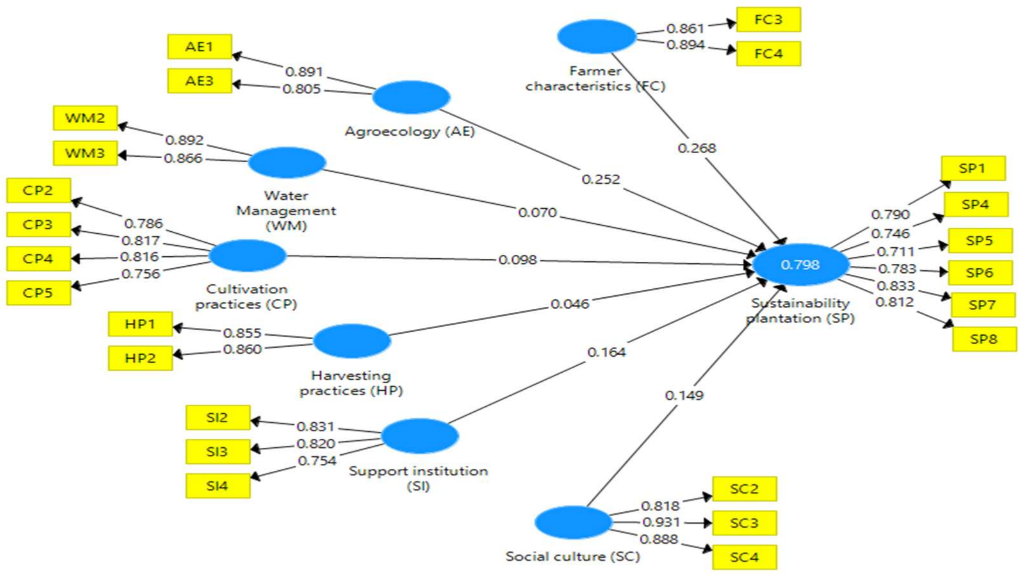

Figure 1. Path diagram and loading factor values after indicator elimination.
Figura 1. Diagrama do caminho e dos valores do fator de carga após a eliminação do indicador.

3.1.1. Reliability and Validity Analysis

Reliability measurement uses Cronbach's Alpha value with criteria > 0.60 as well as composite reliability and composite reliability values > 0.70, although 0.60 is still acceptable (HAIR et al., 2017). Furthermore, convergent validity is measured using AVE with criteria > 0.50. Convergent validity is the extent to which one item shows a positive relationship with other comparable characteristics. The results of validity and reliability analysis are presented in Table 4. Based on the table, it can be observed that all variables are declared valid and reliable.

3.1.2. Discriminant validity

Discriminant validity shows the extent to which a variable differs from others theoretically and is empirically proven through a statistical test. The value of discriminant validity is evaluated through the Fornell-Larcker value. Moreover, the Fornell-Larcker criterion is that the correlation value of each variable is greater than the correlation between others. Table 7 shows that each value is greater than the correlation between others. This shows that all latent variables have good construct and discriminant validity.

3.1.3. Structural model test (inner model)

A structural model describes the relationship between latent variables evaluated using R-squared and path coefficients.

3.1.4. Coefficient of determination (R^2)

The R^2 value for the sustainable plantations model is 0.798, which shows a strong model. Therefore, the R^2 value shows that the variability of the sustainable plantations model can be explained by the variability of exogenous variables by 79.8%. Based on the criteria CHIN (1998), the sago plantations model shows a strong value.

3.1.5. Hypothesis test (Bootstrapping)

Path coefficient and t-statistic values were obtained through the bootstrapping process. The hypothesis test was carried out with a significance level of 5% (p-value <0.05). Based on the results of the bootstrapping analysis (Table 9), the variables of farmer characteristics (FC), agroecology (AE), cultivation practices (CP), socio-culture (SC), and supporting institutions (SI) had a significant effect on the sustainability of sago plantations. Meanwhile, harvesting practices (HP) and water management (WM) did not have a significant effect on the sustainability of sago plantations in Indragiri Hilir Regency. The hypothesis test results (bootstrapping) are shown in Table 6.

3.2. Local wisdom forms in sago plantations management

Unique socio-cultural and ecological conditions produce knowledge through adaptation to the surrounding natural conditions. Identifying local knowledge and wisdom that is deeply rooted in local areas is essential for sustainable agriculture. As a plant that has been closely related to the lives of the Indragiri Hilir community for several years, sago has produced practical knowledge and social, spiritual values, and norms in the form of local wisdom. This local wisdom plays a role in supporting environmental, social, and economic balance. The results of the identification of local wisdom in sago plantations management are shown in Table 7.

Table 4. Cronbach's alpha and composite reliability.
Tabela 4. Alfa de Cronbach e confiabilidade composta.

No	Variable	Cronbach's Alpha	Composite reliability	AVE	Description
1	Agroecology (AE)	0.618	0.837	0.721	Valid and Reliable
2	Cultivation practices (CP)	0.809	0.872	0.631	Valid and Reliable
3	Farmer characteristics (FC)	0.703	0.870	0.770	Valid and Reliable
4	Harvesting practices (HP)	0.640	0.847	0.735	Valid and Reliable
5	Social culture (SC)	0.854	0.911	0.775	Valid and Reliable
6	Supporting institution (SI)	0.725	0.844	0.644	Valid and Reliable
8	Water Management (WM)	0.707	0.872	0.773	Valid and Reliable
7	Sustainability (SP)	0.871	0.903	0.609	Valid and Reliable

Source: output SEM-PLS, 2024.
Fonte: saída SEM-PLS, 2024.

Table 5. Fornell-Larcker Criterion.
Tabela 5. Critério de Fornell-Larcker.

No	Variable	Agroecology (AE)	Cultivation practices (CP)	Farmer characteristics (FC)	Harvesting practices (HP)	Social culture (SC)	Supporting institution (SI)	Water Management (WM)	Sustainability (SP)
1	Agroecology (AE)	**0.849**							
2	Cultivation practices (CP)	0.628	**0.794**						
3	Farmer characteristics (FC)	0.759	0.568	**0.878**					
4	Harvesting practices (HP)	0.656	0.656	0.711	**0.85**				
5	Social culture (SC)	0.648	0.524	0.676	0.651	**0.880**			
6	Supporting institution (SI)	0.705	0.548	0.715	0.674	0.736	**0.803**		
7	Sustainability (SP)	0.804	0.647	0.810	0.714	0.741	0.765	**0.780**	
8	Water Management (WM)	0.637	0.587	0.634	0.577	0.659	0.537	0.670	**0.879**

Source: output SEM-PLS, 2024.
Fonte: saída SEM-PLS, 2024.

Table 6. Significance test results.
Tabela 6. Resultados do teste de significância.

Hypothesis	Original Sample	Sample Mean	Standard Deviation	T stat	P Values	Decision
Agroecology (AE) -> Sustainability plantations (SP)	0.252	0.249	0.052	4.838	0.000	Significant
Cultivation practices (CP) -> Sustainability plantations (SP)	0.098	0.097	0.046	2.116	0.035	Significant
Farmer characteristics (FC) -> Sustainability plantations (SP)	0.268	0.266	0.065	4.157	0.000	Significant
Harvesting practices (HP) -> Sustainability plantations (SP)	0.046	0.043	0.048	0.950	0.342	Not Significant
Social culture (SC) -> Sustainability plantations (SP)	0.149	0.145	0.045	3.268	0.001	Significant
Supporting institution (SI) -> Sustainability plantations (SP)	0.164	0.168	0.056	2.915	0.004	Significant
Water Management (WM) -> Sustainability plantations (SP)	0.070	0.078	0.048	1.467	0.143	Not Significant

Table 7. Local wisdom forms in sago plantations management in Indragiri Hilir Regency.
Tabela 7. Formas de sabedoria locais na gestão de plantações de sagu na Regência de Indragiri Hilir.

Process	Description	Local wisdom form
Pre-planting	- Zoning system of land use for conservation land, sago plantations, settlements, and coconut plantations. - Use of former submerged coconut plantation land as a new zone for sago planting - Water management of a ditch system consisting of a main ditch, secondary ditch, and tertiary ditch. - Selection of varieties based on soil type, peat depth, and salinity level	- Ecological wisdom - Ecological wisdom - Ecological wisdom - Ecological wisdom
Planting and maintenance	- Respect for elders, namely planting a garden in one family, starting from the oldest sibling in the area closest to the river. - Respect for spiritual entities, namely the prohibition of planting sago in the afternoon, and the shadow of the tree must not fall on the planter. The word planting should not be used, but the term *mengalih-alih abot anak sagu* (moving sago sucker) - Creating new gardens and maintaining the *parit kongsi* through mutual cooperation. - Selection of seeds to be used, namely seedlings that look good or seedlings from cut trunks, taken a maximum of 2 days ago - Use of local resources in the form of crop residues and felling as a source of organic material to reduce the use of chemical fertilizers and reduce costs. - The *"tebas lorong"* system, namely, land clearing only in the alleys between clumps.	- Social wisdom - Spiritual wisdom - Social wisdom - Technical wisdom - Economic and ecological wisdom - Economic wisdom
Harvesting	- Determining the right harvest time at the generative stage (*menyorong*) can maintain the sustainability of sago succession and prevent damage to the clump. - Respect for spiritual entities in the form of beliefs prohibiting work on Fridays and prohibiting carrying logs by carrying them on the shoulder. - Use of traditional cutting tools to avoid land damage and pollution. - The method of removing sago trunks by rolling, called *menggolek*, can avoid land compaction. - Soaking logs after harvesting to maintain the quality of starch and avoid losses due to pig and monkey pest attacks. - The method of transporting logs from plantations to the factory through the river. This is performed by assembling in large quantities and pulling using a motorboat called a *menarik tual,* allowing for more effectiveness and efficiency. - Informal conflict resolution system through alternative dispute resolution (ADR) and the principle of family.	- Technical wisdom - Spiritual wisdom - Ecological wisdom - Technical wisdom - Technical wisdom - Economic wisdom - Social wisdom
Marketing	- Social values in the form of a spirit of mutual cooperation, mutual assistance, and kinship between farmers, harvesters, and buyers. - A sago trading system based on mutual trust.	- Social wisdom - Social wisdom
Cultural and traditional ceremonies	- The *Bele Kampong* ritual is a joint prayer around the village to ask for blessings for the village and blessings for the crops. - The tradition of *menangkop sagu,* typical culinary *sago rendang, sago lemak, sempolet,* and other typical dishes	- Spiritual wisdom - Cultural wisdom

Source: Interview and observation results, 2024.
Fonte: Resultados de entrevistas e observações, 2024.

Local wisdom in managing sago plantations is found from the pre-planting stage to marketing. At the pre-planting stage, farmers create a land zoning system according to its designation (Figure 2). Farmers also create water channels in the form of ditches for management and transportation facilities.

For planting, farmers select sago varieties based on soil type and salt content, as the cultivation areas have low salinity influenced by ebb and flow. To maintain land moisture and minimize the application of external inputs in the form of chemical fertilizers, farmers use litter from pruning fronds. During harvesting, farmers identify suitable trunks for cutting by observing the flowering stage when the starch content is the highest Chua et al. (2021). Subsequently, the harvested sago trunk is cut into a log 1.2 m called *tual*, removed from the garden by rolling and soaked in a ditch or river to prevent rotting as well as consumption by pigs and monkeys. According to Tampubolon et al. (2021), the practice of log soaking maintains starch quality and does not rot easily. After obtaining a sufficient number, logs are taken to the factory by assembling and pulling using a motorboat. The method of rolling and pulling is more efficient for swampy areas, minimizing negative impacts on the environment, such as soil compaction. This management practice is in the form of social spiritual values, such as the spirit of mutual cooperation, kinship, and mutual assistance. Furthermore, there are spiritual values in the form of beliefs or myths that can create harmonious relationships with nature.

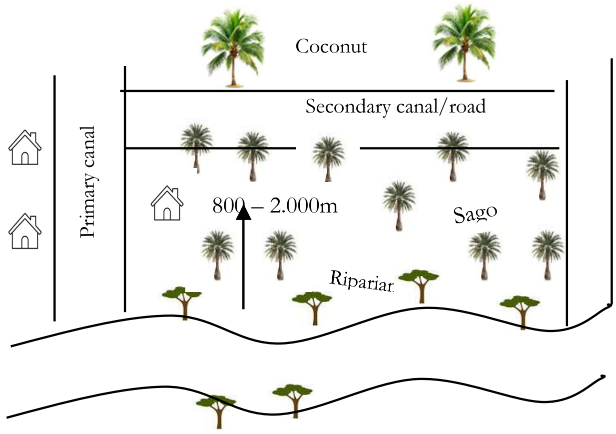

Figure 2. Illustration of land use zoning.
Figura 2. Ilustração do zoneamento do uso do solo.

4. DISCUSSION

4.1. The influence of management practices on sustainability

The management of sago plantations by the Indragiri Hilir community is based on methods used from one generation to another, serving as local knowledge appropriate to environmental conditions. Additionally, social and cultural dynamics produce socio-spiritual values that play a role in maintaining environmental and economic balance. These values and practices serve as local wisdom essential to the sustainability of sago plantations. Based on the quantitative analysis, the results show that characteristics of farmers, agro-ecological conditions, cultivation practices, supporting institutions, and social values significantly affect the sustainability of sago plantations. However, water management and harvesting practices are sub-optimal, showing insignificant effects.

The characteristics of farmers based on experience and motivation influence management practices to create sustainable sago plantations. Generally, experience can increase the level of skills and knowledge in a particular practice (BURTON, 2014). In this study, the majority of respondents have been included in sago farming for more than 10 years (43.93%) and 20 years (24.64%). These experienced farmers often have a deeper understanding of agroecological conditions, harvest cycles, and effective cultivation practices. Additionally, psychological factors in the form of motivation to grow sago play an important role in determining farmers' behavior and decisions. Based on the interview results, farmers still have enthusiasm for sago due to several factors, including ease of maintenance, source of family income, a consistent increase in selling price, and cultural significance as an inherited legacy. The following are the results of an interview with one of the sago farmers:

> *"This sago has been around since our grandmothers' time. This sago is an heirloom from our parents; we don't want to sell it. Once planted, it won't run out for seven generations. Moreover, this sago is easy to care for. Even if it is not cared for, it will live*". (*Jasmin- Sago Farmer, 2024*)

Farmers' knowledge in selecting planting areas according to agroecological requirements is a legacy obtained from previous generations. Arranging land-use areas is important to ensure economic, ecological, and social functions. In addition to being commercial crops, sago plantations also function as buffer zones between rivers and coconut plantations. This division of zones is ecological wisdom that plays a role in maintaining a balance between the economy and environmental preservation.

Cultivation practice by farmers in the upstream areas after the nipah vegetation shows low salt content and has freshwater flow. These areas are crucial, as ebb and flow are natural mechanisms to regulate soil acidity and remove toxic substances through soil washing. The movement of water also helps distribute nutrients and sediment needed for sago growth, providing suitable environmental conditions for the growth of microorganisms (BINTORO et al., 2018). However, the Indragiri Hilir area is located on the coast affected by significantly high tides, which bring seawater with high salt content upstream when the north wind blows. Although sago is tolerant of saltwater, long-term exposure to high salinity can interfere with plant growth and productivity. High sodium levels also have the potential to inhibit nutrient and water absorption, causing plant stress characterized by suboptimal sago stem growth (EHARA, 2018).

In this study, cultivation practice carried out by the community is in line with the concept used by the LEISA (Low external input sustainable agriculture) system, which emphasizes the absence of using chemical fertilizers. Therefore, this plant is relatively safe from pest attack, as control measures are performed biologically without chemicals. The nutrient needs of sago can be fulfilled from the overflow of mud from upstream during ebb and flow. Furthermore, Nemenzo et al. (2012) stated that there were nitrogen-binding bacteria in the sago root area, namely *Bacillus subtilis*, *Agrobacterium tumefaciens*, and *Pseudomonas veronii*, allowing the fulfillment of nitrogen needs. Litter from pruning and felling sago trees is left in the garden as a source of organic material and to maintain land moisture. Okazaki; Sasaki (2018) also stated that fertilizer application did not have a significant effect on the growth of sago on peat soil.

Although sago can grow with minimal care, routine maintenance is still essential in the form of reducing shoots and pruning fronds. The long harvest period makes farmers less intensive in managing the gardens (Chua et al., 2021), which contributes to low productivity. To address these challenges, appropriate institutional and policy support can help ensure sustainable management. According to Uphoff (1992), the existence of local institutions plays a role in increasing group capacity, which drives sustainability. Efforts to reach the community through local institutions also have psychological value because of obedience to customary rules

(WAHYU et al., 2024). The existing forms of local institutions include non-formal farmer groups (*paguyuban*) and informal conflict resolution. Limited access to transportation and extension services makes it difficult for areas to be reached by government programs that require farmers to join formal groups. Therefore, farmers form non-formal groups (*paguyuban*) as a forum to discuss solutions to various problems, such as price negotiations and market access.

Conflict that often occurs due to disputes over plantation boundaries and logging errors requires a family-based resolution, limiting the occurrence of resentment in the future. The non-formal conflict resolution mechanism is carried out through deliberation mediated by community leaders or village heads. This type of resolution model is considered more flexible, produces mutually beneficial solutions, and avoids resentment in the future (MEHRL; BOHMELT, 2021). As an important social institution that is not officially recorded in the judicial system, the model helps in building and maintaining social order as well as supporting fairer and more acceptable decisions for all parties. This is supported by the statement from the Head of Simpang Kateman Village as follows:

> *"I have resolved many disputes over sago palm land. Loggers often cross the garden boundary ditch, hence causing wrong felling. Here, the settlement system is amicable; those who cut down wrongly must compensate for the loss. If the case goes to the police, there is none, but there are witnesses from the police" (Sunito, 2024).*

Social values in the community, in the form of a spirit of kinship and mutual cooperation, are the basis for interaction. The cooperation system is a collective work that has become local wisdom in Indonesia, including the community in Indragiri Hilir. These values are very important social capital for rural communities faced with financial capital constraints (SLIKKERVEER, 2019; LUKIYANTO; WIJAYANINGTYAS, 2020). Additionally, social values can increase cohesion within the group and strengthen the capacity to realize sustainable plantations. The spirit of kinship often underlies the buying and selling system. In many cases, farmers and buyers set prices based on economic considerations and elements of mutual benefit. Cooperation activities carried out by farmers during land clearing, planting, cleaning transportation routes (*washing ditches*), and other public facility maintenance activities can reduce costs. Land clearing and planting require large financial capital, although farmers can reduce costs through cooperation.

Sago harvesting practices are full of local wisdom that is environmentally friendly. However, the practices are suboptimal, showing an insignificant effect on plantation sustainability. Farmers' knowledge of the criteria for stems ready to be cut (*menyorong*) is very important for determining the quality of sago produced and maintaining harvest rotation. This is because a lack of innovation in harvesting practices and poorly maintained garden conditions cause gardens to become overgrown, leading to expensive processing costs and reduced farmers' income. The suboptimal water management system only functions as a transportation route. Therefore, water management is important to maintain humidity, which can prevent land fires, specifically in peatlands (YULIANI; ERLINA, 2018).

4.2. Collaboration of local wisdom and science-based knowledge

The practices and values of local wisdom are very close in the management of sago plantations in Indragiri Hilir Regency. However, there is a need for improvement through innovation and collaboration with science-based knowledge. The dynamic nature of local wisdom enables the adoption of technological developments, social conditions, and the environment. Increasing farmers' awareness through collaboration that combines local and scientific knowledge has been proven to support the sustainability of the agricultural system (ŠŪMANE et al., 2018; AKSOY; ÖZ, 2020; FLOOD et al., 2022). Regarding sago, the low productivity needs to be increased by improving cultivation practices. The agricultural system carried out by farmers traditionally is capable of protecting the environment, but has not been able to optimize production. Therefore, innovation is needed through the collaboration of local knowledge with science-based knowledge. Collaboration of informal and formal institutions is also essential to strengthen the role of extension workers who provide an important understanding and enhance members' participation. The inclusion of formal law enforcement, such as the police, in resolving informal conflicts will provide stronger results.

In this study, harvesting and water management are carried out sub-optimally, showing insignificant effects on the sustainability of sago plantations. One main challenge is the poor maintenance of the sago garden, leading to heavy harvesting work and the need for large resources. The heavy harvesting process causes expensive farming processes, which reduces farmers' income. For example, with an average sago selling price of IDR 36,000/log and a harvesting cost of IDR 11,000/log, the harvesting cost reaches 30.55%. To address these challenges, a small number of harvesters have started using a tool called a *kiu* or *jek* (Figure 3). This tool is claimed to be easier and more ergonomic, but has not been widely applied by harvesters.

Figure 3. Innovation of a tool for digging using a "*kiu* or *jek*".
Figura 3. Inovação de uma ferramenta de escavação usando um "*kiu ou jek*".

The existing water management system is only intended for transportation routes, but is not regulated in a way to support plant growth. However, the canal-blocking system through community-owned water gates known as *tabat* is not implemented. A system like this needs to be applied to sago plantations far from rivers, where the soil type is peat and is only exposed to overflow during high tides. According to Tampubolon et al. (2021), the sago plant that lives in high groundwater conditions, with a level of 6.8 cm, produces the most optimal stem growth (IRAWAN et al., 2024).

5. CONCLUSIONS

The selection of planting areas had a significant positive influence on the sustainability of sago plantations based on social values, norms, and institutions. Cultivation practices that minimized the use of external inputs showed positive effects on the environment. However, suboptimal harvesting and water management practices had an insignificant positive effect on sustainability. The results also showed that heavy harvesting practices and a lack of innovation led to high operational costs, thereby reducing farmers' income. Similarly, water management that only functioned as a transportation route had not been optimized to support plant growth.

Local wisdom found in sago management from pre-planting to marketing showed a positive effect on economic, social, and environmental sustainability. At the pre-planting stage, the division of land use area functioned to ensure proper usage. During planting, the selection of appropriate varieties and areas, together with respect for social and spiritual values, ensured successful growth. At the harvesting stage, knowledge and practical technology were used to maintain ecological and economic balance. Social values and non-formal institutions also supported the process of interaction between stakeholders. This dynamic nature of local wisdom allowed the adaptation to changing knowledge, environmental conditions, and community needs. When traditional practices no longer fulfilled the requirement for productivity and efficiency, an innovative method could be adopted in collaboration with science-based knowledge.

In this study, the water management system that only acted as a transportation route needed to be developed by creating tidal-based water gates, providing optimal groundwater levels for sago growth. Regarding harvesting practices, the use of digging and pulling logs was proven to be an effective and environmentally friendly method. The innovation of a tool called *Jek* required implementation, allowing for a more practical and ergonomic digging process.

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