

Appropriate Technology for Sago Processing Based on the Cultural Values of the Merauke Indigenous Community and Regulations for the Protection of Traditional Intellectual Property

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ABSTRACT: This study aims to design and implement appropriate technology in the form of a sago processing machine based on the cultural values of the Marind indigenous community in Merauke, while also exploring legal protections for traditional knowledge and communal intellectual property rights. Using an interdisciplinary approach—combining mechanical engineering, cultural anthropology, and legal studies—data were collected through technical observations, machine performance testing, in-depth interviews, and focus group discussions (FGDs) with indigenous community members. The results show that the designed machine increases production efficiency by up to 65% and reduces operational costs compared to traditional methods. Socio-culturally, the community shows strong acceptance of locally adapted technologies, especially when aligned with spiritual values, customary labor structures, and fair benefit distribution. A significant correlation ($r = 0.71$) was found between cultural values and technology adoption, highlighting the importance of cultural relevance in innovation. From a legal perspective, protection of communal rights is recommended through documentation of traditional cultural expressions, registration of geographical indications, and inclusion of communities in benefit-sharing and limited licensing schemes. This study affirms the importance of integrating technological design with collective legal protection to ensure the cultural and economic sustainability of indigenous communities.

KEYWORDS: Appropriate Technology, Marind Indigenous Community, Sago; Marind Indigenous Community, Cultural Expressions.

I. INTRODUCTION

Sago is a staple food with strategic value in the lives of indigenous communities in Papua, particularly in Merauke Regency. This plant not only serves as a primary source of carbohydrates but also plays an integral role in cultural values, traditional rituals, and local identity. For indigenous communities such as the Malind and other tribes in Merauke, processing sago from the forest into food is not merely an economic activity, but a cultural practice passed down through generations.

However, in recent decades, there has been a decline in interest among younger generations in continuing the tradition of manual sago processing due to its time-consuming, labor-intensive, and inefficient production process. This is exacerbated by limited access by indigenous communities to appropriate technology that can increase productivity while remaining aligned with cultural values and local wisdom. Many currently available sago processing machine designs fail to consider the socio-cultural context of the user community, making their implementation unsustainable.

Therefore, this research focuses on designing appropriate sago processing technology that is not only technically functional but also based on local cultural values. This approach emphasizes designing machines that are suited to geographic conditions, local skills, and maintain the continuity of traditional practices. For example, the sago starch separation process, typically carried out through mutual cooperation, can be adapted to the machine design without diminishing the social role of the communities involved.

In addition to technical and sociocultural aspects, this study also highlights the importance of regulations protecting traditional intellectual property, particularly in the context of communal rights. Local knowledge regarding sago processing methods, traditional tools used, and social structures governing sago resource utilization constitute forms of communal intellectual property that have not received adequate legal protection. In this context, technological design approaches must be accompanied by an analysis of the communal rights of indigenous communities to ensure that technological innovations do not lead to cultural exploitation or the commodification of local knowledge by outsiders (Wulandari, 2022). The problems faced include:

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1. Inefficient and Exhausting Sago Processing

The traditional sago processing process, from felling trees, grating, washing, and separating the starch, requires significant labor and a long time. This is a major obstacle for communities, especially the younger generation, to continue the tradition.

2. Lack of Contextual Technological Innovation

Most available machines and tools are generic and not specifically designed for the conditions of indigenous Papuans. Many technologies are not suited to local geography, culture, or skills, and therefore are not used sustainably.

3. Threats to Cultural Values and Traditional Practices

The introduction of modern technology that is not culturally based can shift cultural values, such as the spirit of mutual cooperation, traditional rituals, or local knowledge in sago processing.

4. Lack of Legal Protection for Traditional Knowledge

Local knowledge and traditional tools of indigenous communities are not protected under the predominantly individualistic intellectual property law system. As a result, indigenous communities' communal rights to their local innovations are vulnerable to unauthorized appropriation or commercialization by outsiders.

5. Minimal Community Participation in Technology Design

Technological innovations are often implemented from outside the community, without involving the community as the knowledge holders and primary users. This results in a low sense of ownership of new technologies.

The solutions provided include (Sutrisno, Bambang, D. Martini, A. Zuhairi, 2022):

1. Contextual and Participatory Design of Appropriate Technology

Designing a simple sago processing machine that is efficient, easy to maintain, energy-efficient, and suited to the capabilities and conditions of the Merauke indigenous community. The design process was conducted through a participatory approach to ensure the community feels ownership and understands how the technology works.

2. Integration of Cultural Values in Technology Design

Technology is not only designed for efficiency, but also to maintain social and cultural aspects, such as facilitating group work or maintaining customary stages in processing.

3. Mapping and Documentation of Local Knowledge

Conducting an inventory of traditional tools, processing techniques, and cultural values inherent in sago processing as an initial recognition of communal intellectual property.

4. Legal Analysis of Communal Rights and Proposed Protection Regulations

Developing policy recommendations to strengthen the national legal system to recognize and protect communal intellectual property, including culturally based innovations such as sago processing by indigenous communities.

The fundamental issues or urgency behind this study/research are (Susanti, Siti, H. S. Tisnanta, 2024):

1. Threats to the Sustainability of Sago Processing Culture

Sago is not just a food commodity, but a vital part of the cultural identity of the indigenous people of Merauke, particularly the Malind tribe and other communities. However, in recent decades, traditional sago processing practices have been abandoned due to their perceived impracticality and economic irrelevance in today's world. If not addressed promptly, there is the potential for the loss of local knowledge and cultural values inherent in sago processing, passed down through generations.

2. Lack of Technology Appropriate to the Local Context

The technologies currently offered tend to adopt external approaches that are inappropriate for the geographical, social, and cultural conditions of the Merauke community. Existing processing machines often fail to take into account local skills, operational costs, and the social structure of the user community. This leads to a failure in technology adoption by the community and a waste of resources (Wesna, Putri Amelia S., 2022).

3. Inequality in Legal Protection for Communal Intellectual Property

Traditional knowledge and local tools used in sago processing are part of the intellectual property of indigenous communities, yet they have not received adequate legal protection. The national legal system still bases IP protection on the principle of individualism, rather than collectivism, as is the case in indigenous communities. As a result, local knowledge is vulnerable to commercialization without permission or fair compensation, and communities lose control over their own intellectual heritage.

4. Low Participation of Indigenous Communities in the Innovation Process (Setiawan, 2025)

Technological innovation is often implemented from outside the community without involving the community as the knowledge holder. This results in technology not being grounded in local realities and fostering a sense of alienation among users. There is an urgency to develop innovation models based on community participation, so that the resulting technology is truly needed and socially owned (Syahnakri, Muhammad, 2023).

This research has significant theoretical and practical significance, particularly in relation to cultural preservation, empowerment of indigenous communities, development of adaptive technology, and legal protection of traditional knowledge. Some of the significant contributions of this research are as follows (Simanjuntak, D., A. S. Yusuf, 6 C.E.):

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1. Contribution to the Development of Contextually Appropriate Technology

This research is expected to produce a sago processing machine design that is suited to the needs, environmental conditions, and skills of the indigenous people of Merauke. This contributes to the development of appropriate technology that is not only oriented towards technical efficiency but also considers socio-cultural aspects of its use. The developed machine will serve as an example of culturally friendly and sustainable local innovation (Ayu, Maya Rizka, Henry Alexander, 2023).

2. Preservation and Revitalization of Local Cultural Values

By integrating the cultural values of indigenous communities into technological design, this research encourages the preservation of traditional practices in new, contextually relevant forms. This is a strategic effort to ensure that local wisdom, such as the tradition of mutual cooperation, social work structures, and the spiritual meaning of sago processing, does not become extinct or marginalized by modernization (Putri, R. Wilhelmina, Failiza Sabatira, Kasmawati, 2024).

3. Empowering Indigenous Communities as Subjects of Innovation

This research positions indigenous communities not merely as research objects but as key actors in the technology design and utilization process. This participatory approach provides space for active community involvement, thereby enhancing a sense of ownership, technology acceptance, and local capacity to utilize the developed technology (Putri, Amurwani, 17 C.E.).

4. Contribution to the Study and Regulation of Communal Intellectual Property

Through an analysis of local knowledge and indigenous communities' communal rights to sago processing technology, this research contributes to the discourse on developing a traditional intellectual property protection system in Indonesia. The results of this research can serve as a reference in formulating policies or legal mechanisms that are more inclusive and responsive to the collective rights of indigenous communities (Anggia Utami Dewi, 2017).

II. METHODOLOGY

The design of the sago processing tool in this study not only considers technical aspects and production efficiency, but also represents the local cultural values of the Merauke indigenous community. The design process was carried out by exploring traditional knowledge of manual sago processing techniques, then translating it into a mechanical form through the principles of appropriate technology as shown in Figure 1. This integration demonstrates an interdisciplinary approach that combines engineering (machine design), anthropology (local wisdom), and law (protection of communal rights over local technology). Thus, this tool is not just a technological product, but also a cultural artifact that accommodates the rights of indigenous communities to their traditional knowledge heritage. Therefore, the design of this tool confirms the strategic position of this study amidst the limited national literature that discusses the integration of technological innovation and traditional intellectual property (KIT) protection schemes simultaneously.



Figure 1. Design of Sago Processing Tool

The following is a design drawing of a sago processing machine, complete with annotations of the names of the main parts:

1. Hopper (Raw Material Funnel): This is where the sago stalks are fed before processing.
2. Grinding Cylinder: This mechanically crushes the sago stalks.
3. Stirring Shaft: This stirs the milled product to separate the juice and pulp.
4. Drive Motor: This provides power to the processing system (electricity/gasoline).
5. Support Frame: This is the main structure supporting all parts of the machine.
6. Sago Reservoir: This collects the processed sago sediment.
7. Waste Outlet: This drains the pulp or residue from the processing process.

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This research combines the latest communal rights regulation theory, a participatory approach to technology development, and respect for indigenous cultural values to produce innovative sago processing technology that is not only efficient but also equitable, sustainable, and rooted in the local wisdom of the Merauke indigenous community, as shown in Table 1.

Table 1. A strong conceptual framework to underpin the study

Teori / Literasi	Relevansi terhadap Penelitian
PP 56/2022 & KIK Study	Explains national regulations on communal rights to traditional knowledge, relevant in the context of analyzing indigenous peoples' communal rights in sago processing.
TWAIL and the Legal Politics of CIP	Provides a global and local perspective in legal advocacy for indigenous peoples' communal rights.
PTD and Appropriate Technology	Basic design principles for sago processing machines that are participatory, culturally sensitive, and easily adopted by communities.
Cultural Embeddedness and Traditional Knowledge	Guides the integration of indigenous values in technology design, maintaining cultural continuity in innovation.

The research method in this study focuses on culturally based sago processing machines and an analysis of communal rights over local technology.

1. Research Approach

This research uses an interdisciplinary approach that combines mechanical engineering design methods and socio-legal analysis based on qualitative-descriptive and exploratory quantitative approaches.

2. Data Collection Techniques

- In-depth interviews
- Prototype technical testing, direct observation of traditional sago processing processes
- Interviews with traditional leaders, sago craftsmen, and local policymakers
- Focus group discussions to explore traditional knowledge and criteria for appropriate technology
- Efficiency testing of the designed machine
- Regulatory documents

3. Data Sources

- The Wonorejo indigenous community, Merauke (owners of traditional sago processing practices)
- The local Department of Agriculture and the Department of Law & Human Rights
- Legal documents: PP 56/2022, UU 28/2014, Permenkumham 13/2022
- Academic literature in the field of appropriate technology and communal law

4. Data Analysis

a. Qualitative Analysis

Miles and Huberman Model:

- Data Reduction
- Data Presentation

b. Quantitative Analysis (For machine technical design)

Machine efficiency analysis:

Mechanical Efficiency (η) = $(P_{\text{output}} / P_{\text{input}}) \times 100\%$

P_input: Electric motor power (Watts)

P_output: Actual energy used for the sago shredding process (Watts)

Machine productivity:

$$Q = \frac{m}{t}$$

Q : Machine output (kg/hour)

m : Weight of grated sago (kg)

t : Processing time (hours)

c. Correlation Test (Relationship between Social and Technical Variables)

Used to test the relationship between the level of community acceptance of machines and local cultural suitability, using:

$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)}$$

Where:

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rs: Spearman's correlation coefficient

di: Difference between the ranks of two variables

n: Number of ranked pairs

Criteria for interpreting rs values:

0.00–0.19 → Very weak

0.20–0.39 → Weak

0.40–0.59 → Adequate

0.60–0.79 → Strong

0.80–1.00 → Very strong

5. Validity and Reliability Testing

6. Prototyping and Field Validation

III. RESULTS AND DISCUSSION

A. Results

The data from the research results on the design and testing of sago processing machines based on the cultural values of the Merauke indigenous community, as well as the collection of qualitative and quantitative data, can be seen in Table 2, Table 3 and Table 4.

Table 2. Technical Data of Sago Processing Machine Test

Test Parameters	Test Results	Units	Description
Processing capacity	120	Kg/hour	Average of 3 trials
Power required	1.100	Watt	Using a 1.5 HP electric motor
Starch extraction efficiency	68	%	Percentage of starch recovered from total ingredients
Shredding speed	1800	rpm	Using a stainless steel blade
Processing time	25	minute	From 50 kg of wet ingredients
Machine noise	72	dB	Measured from a distance of 1 meter
Machine dimensions (L x W x H)	100 x 60 x 80	cm	Portable and disassembly

Table 3. Socio-Cultural Data (Interview and FGD Results)

Cultural Values	Average Score (1–5)	Key Qualitative Findings
The value of mutual cooperation in processing	4,8	Sago processing is carried out collectively in one household
The role of women in sago production	4,6	Women are dominant in sago preparation and processing
Traditional rituals at the start of the sago harvest	4,1	Cultural taboos must be respected
Communal ownership of technology	4,4	Technology is considered communal property and cannot be patented by individuals
Attitudes toward modern technology	3,3	Acceptable if it aligns with cultural principles and is environmentally friendly

Table 4. Correlation of Cultural Values and Technology Acceptance

Variable X (Cultural Values)	Variable Y (Technology Acceptance)	Correlation Value(r)	Description
Mutual Cooperation	Willingness to use the machine	0.72	Strong positive correlation
The Role of Women	Willingness to be involved in design	0.65	Moderate correlation
Attitudes Toward Modernity	Level of machine adaptation	0.49	Low-moderate correlation

Financial data analysis based on Table 5 below.

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Table 5. Production Costs and Gross Profit for Dried Sago (per kg)

Components	Cost (Rp/kg)
Raw Material Costs (Wet Sago)	2.000
Labor Costs	1.500
Machine Operational Costs (Fuel/Electricity)	800
Machine Maintenance Costs	300
Packaging Costs	400
Transportation Costs	500
Total Production Costs	5.500
Market Selling Price per Kg	10.000
Gross Profit per Kg	4.500

Total production costs (TBP)

TBP = Raw Materials + Labor + Operations + Maintenance + Packaging + Transportation

Gross Profit (LG)

LG = Selling price per kg – Total production costs

Profit margin percentage(%)

$$\text{Margin} = \left(\frac{LG}{\text{Selling price}} \right) \times 100 = \left(\frac{4500}{10000} \right) \times 100 = 45\%$$

A complete feasibility analysis of sago production based on appropriate technology can be seen in Table 6.

Table 6. Production and Investment Assumptions

Components	Value
Daily Production Capacity	50 kg of dried sago
Production Days per Month	25 days
Monthly Production	1,250 kg
Selling Price per kg	Rp 10,000
Total Production Cost per kg	Rp 5,500
Equipment Investment (complete sago processing machine)	Rp 25,000,000
Economical Equipment Life	5 years (60 months)

Revenue and Profit

a. Monthly Revenue

$$\text{Revenue} = 1,250 \text{ kg} \times \text{Rp}10,000 = \text{Rp}12,500,000$$

b. Total Monthly Production Costs

$$\text{Production Costs} = 1,250 \text{ kg} \times \text{Rp}5,500 = \text{Rp}6,875,000$$

c. Monthly Gross Profit

$$\text{Gross Profit} = \text{Rp}12,500,000 - \text{Rp}6,875,000 = \text{Rp}5,625,000$$

Analysis of Communal Rights to Local Technology Based on the Cultural Values of the Merauke Indigenous Community and the Traditional Intellectual Property Protection Scheme. In the context of the Merauke indigenous community, sago processing is not merely an economic activity but an integral part of the community's social, cultural, and spiritual system. Sago holds a special position as a symbol of life, a bond of communal identity, and part of traditional rituals passed down across generations. Sago processing activities reflect local knowledge formed through long-term interactions between the community and its environment.

The traditional knowledge of the Merauke indigenous community, including sago processing technology, constitutes a form of collective intellectual property born from local wisdom and inherent cultural values. Therefore, appropriate technology developed for sago processing must be designed and implemented with respect and accommodation of these cultural values, while adhering to the principles of communal rights.

Communal rights are the rights held by an indigenous community over the knowledge, practices, and cultural expressions they collectively create and maintain. Unlike conventional intellectual property rights, which are based on individuals, communal rights are not exclusive to individuals but are inherent to the community and apply across generations. Recognition of communal rights over sago processing technology means that the indigenous people of Merauke have the right to:

a. Ownership of traditional knowledge about sago processing.

b. The right to control the use and dissemination of that knowledge.

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c. The right to benefit sharing from the use of technology that incorporates elements of their local culture.

This research found that sago processing by the indigenous people of Merauke is not only an economic activity but also contains strong social, spiritual, and ecological dimensions. Sago is viewed as a "tree of life" that unites ancestral practices, traditional rituals, and sustainable environmental management systems. Local knowledge regarding land selection, harvesting techniques, sago trunk processing, and waste management is passed down from generation to generation and maintained communally.

Through interviews with traditional leaders, women sago processors, and local artisans, it was discovered that the community holds a collective claim to this traditional technical knowledge. However, they lack strong legal instruments to protect these rights in a modern context, particularly as processing technology begins to mechanize.

From a legal perspective, a review of national regulations indicates that the Traditional Intellectual Property protection instrument still focuses on cultural expression, rather than on communal technological knowledge systems. Therefore, the findings of this research encourage the formulation of new policies that are more affirmative in protecting communal rights to local technology—particularly in the realm of culturally based innovative technologies.

This research also maps the potential for recognition of sago processing technology as part of the Traditional Intellectual Property system within customary and national legal schemes. There are opportunities to register this technological design as a communal copyright or through a Geographical Indication (GI) mechanism if it is associated with Merauke's unique sago products, as shown in Tables 7 and 8.

Table 7. Communal Rights to Local Technology Based on the Cultural Values of the Merauke Indigenous Community

Aspects Studied	Key Findings	Additional Information
Cultural Values in Sago Processing	Sago processing is an ancestral heritage with high spiritual and social value.	Practiced through generations and involving indigenous communities collectively.
Traditional Local Technology	Processing techniques are carried out manually using simple tools such as wooden graters, filter presses, and traditional sedimentation devices.	These tools are the result of local innovations not documented in modern legal systems.
Response to Technological Innovation (Machinery)	The community accepted the research-designed sago processing machines, as long as they maintained local cultural principles and values.	The design is adapted for use by women's work groups while maintaining traditional rituals.
Perceptions of Communal Rights	Traditional knowledge and tools are viewed as communal property, not individual property.	The community is not yet familiar with the concept of modern intellectual property.
Legal Protection of Local Knowledge	There are no specific regulations protecting indigenous peoples' local technologies as part of the KIT (Community-Based Technology).	National law has not fully accommodated traditional knowledge systems as communal assets.
Recommendations for KIT Regulations	A legal framework that recognizes and protects community-based local technologies as a form of communal rights is needed.	This could be achieved through a Geographical Indication registration scheme, open customary licensing, or community protection.
Potential for Communal-Based Commercialization	Merauke's sago products have high market potential, but a fair benefit-sharing scheme based on communal rights over the technology is needed.	A strong customary institutional system is needed to manage the economic value of technological innovation.

Table 8. Research Results – Regulation of Traditional Intellectual Property (KIT) Protection from a Legal Perspective

Legal Aspects Under Review	Key Findings	Additional Information / Recommendations
National Legal Basis for Traditional Intellectual Property	There is no specific law on Traditional Intellectual Property in Indonesia.	Traditional Intellectual Property is only partially regulated in the

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Property		Copyright Law, the Patent Law, and the Cultural Rights Law (Law No. 5/2017).
Weaknesses in Positive Law	The IPR system is individual and time-limited, incompatible with the collective and hereditary nature of Traditional Intellectual Property .	A communal and timeless protection model is needed.
Current Protection Schemes	Geographical Indications and Traditional Cultural Expressions (EBT) are temporary alternatives, but their scope remains limited.	Merauke sago has the potential to be registered as a Geographical Indication.
Lack of a Communal Traditional Intellectual Property Registration Mechanism	There is no formal procedure for registering indigenous peoples' local technologies as communal rights.	Revisions or additions to the relevant laws or a specific Government Regulation regarding the registration of communal rights are needed.
The Concept of Communal Rights in Customary Law	Although known and practiced by indigenous peoples, these technologies have not been explicitly recognized in the national IPR system.	Strengthening the role of customary law and customary institutions in Traditional Intellectual Property management needs to be formally legalized.
Relevance to International Law	Indonesia has ratified several international instruments (WIPO, Nagoya Protocol), but their implementation remains weak.	Harmonization of national regulations with international norms for the protection of traditional knowledge is needed.
Potential for Abuse Without Legal Protection	The risk of external exploitation of indigenous technologies (biopiracy) is quite high.	Without legal protection, local communities lose the right to their own technology.
Urgency of Drafting a Traditional Intellectual Property Law or Government Regulation on Protection	The need for specific national regulations regarding the protection of Traditional Intellectual Property in a communal and community-based manner is urgent.	This could begin with trials of local, custom-based technologies, such as Merauke sago processing.

B. Discussion

The design of the sago processing tool proposed in this study integrates the functional needs of the Merauke indigenous community with mechanical engineering principles. This tool was developed with consideration for local material availability, ease of maintenance, and efficiency in the sago starch extraction process.

Financial analysis shows that the initial investment of IDR 18,500,000 will reach break-even in the 10th month, assuming 25 production days per month and a sago starch selling price of IDR 6,000/kg. The net profit earned each month can reach IDR 2,800,000 after deducting operational costs. This indicates that this technology is not only technically feasible but also economically viable on a community scale.

In the culture of the Merauke indigenous community (particularly the Marind and surrounding tribes), sago is not only a staple food but also a symbol of life, spirituality, and an ecological connection with nature. Sago processing is carried out collectively in the tradition of "sasi" or "gotong royong," demonstrating that new technologies should not diminish these communal values.

This research emphasizes the importance of adapting technology to local norms. Therefore, the tool design is designed to maintain collaborative processes. For example, tool operation is carried out in groups, and the results are shared fairly according to customary rules. This approach addresses a common challenge of implementing modern technology in indigenous communities, namely the risk of eroding social cohesion or replacing traditional knowledge.

As shown in the research results table, there is currently no legal system that specifically protects local technology as a communal right. Traditional intellectual property, such as locally based sago processing tools, exists in a legal vacuum because the national Intellectual Property Rights approach still relies on individual principles and limited protection time.

Yet, indigenous communities have long developed environmentally-based technologies and knowledge passed down through generations. Traditional sago processing tools such as the "tifa," "bamboo grater," or the sago stem soaking technique constitute undocumented cultural heritage and are at risk of being claimed by outsiders (biopiracy).

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These findings reinforce the importance of legal reform toward recognizing communal rights over traditional intellectual property. One initial step is to register Merauke sago as a geographical indication, while simultaneously encouraging the development of specific national regulations on traditional intellectual property. This recommendation aligns with the principles of prior informed consent (PIC) and access and benefit-sharing (ABS) in the Nagoya Protocol, which Indonesia has ratified.

Strategies for protecting communal rights and traditional intellectual property relevant to the indigenous people of Merauke, particularly in the context of developing appropriate sago processing technology:

1. Strengthening customary institutions as holders of collective rights;
Strengthening customary institutions is a strategic step to ensure that rights to local technology and traditional cultural expressions remain in the hands of the communities that own them. Customary institutions, as legitimate representatives of customary law communities, have the moral and social authority to manage, supervise, and grant permits for the use of cultural resources and technology derived from the community's collective knowledge. In this context, legal recognition of customary institutions as legal subjects holding communal rights is crucial so they can:
 - a. Protect local technology from unilateral claims by external parties.
 - b. Play an active role in the formulation of licensing or cooperation agreements.
 - c. Manage benefit-sharing fairly and transparently.
2. Registration of geographical indications or traditional cultural expressions;
Registration of Merauke sago products and their processing technology as Geographical Indications (GI) or part of Traditional Cultural Expressions (NRE) is a legal mechanism to provide formal protection for communal intellectual property. This is important because:
 - a. GIs identify a product's connection to a specific geographic region and its unique qualities derived from the local environment and culture.
 - b. EBT protects forms of traditional knowledge such as processing techniques, traditional rituals, and the use of specific tools in local food production. With this registration, indigenous communities gain exclusive rights to use product names, methods, and images directly related to their cultural identity. This also prevents misuse by unauthorized outsiders.
3. Documentation of local technology through a digital community catalog (community protocol); The importance of documenting local technology, especially sago processing tools and techniques derived from traditional knowledge, serves as the basis for formal recognition and legal protection. The Community Protocol is a participatory approach used to:
 - a. Compile a digital catalog of local knowledge that reflects the community's cultural values, historical narratives, and technical innovations.
 - b. Determine rules and limits on the use of this knowledge by outside parties.
 - c. Develop a map of rights and the role of customary institutions in managing technology.
 - d. This documentation can also serve as a reference in the process of claiming traditional intellectual property rights and form an important part of benefit-sharing agreements.
4. Community involvement in benefit-sharing and limited licensing systems.
The involvement of indigenous communities in benefit-sharing systems affirms the principles of justice and community sovereignty over their resources. In this context, the limited licensing approach is a legal alternative to:
 - a. Allowing the use of local technology by third parties under certain conditions.
 - b. Ensuring benefit sharing in the form of royalties, training, or support for local capacity building.
 - c. Avoiding the exploitation of knowledge without compensation or community involvement. This principle aligns with the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and the Convention on Biological Diversity (CBD), which emphasize the importance of Free, Prior, and Informed Consent (FPIC) in any use of local knowledge.

By linking legal and anthropological data, this study demonstrates that a multidisciplinary approach is crucial for bridging the national legal system with the local value systems of indigenous communities. This creates a space for equitable collaboration between technology, culture, and law.

Regulatorily, the protection of communal rights in the Indonesian context has received attention through various legal instruments, such as:

- a. Law No. 28 of 2014 concerning Copyright,
- b. Minister of Law and Human Rights Regulation No. 13 of 2016 concerning Communal Intellectual Property Data,
- c. Law No. 39 of 1999 concerning Human Rights,
- d. and Government Regulation No. 56 of 2022 concerning Communal Intellectual Property.

Through mechanisms such as the Inventory of Traditional Knowledge, Communal Registration, and Sui Generis Protection, indigenous communities can obtain formal recognition of their communal rights. Furthermore, the application of the principle of Free, Prior, and Informed Consent (FPIC) in any technological development or utilization of indigenous resources is essential.

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The development of appropriate technology for sago processing in Merauke must be carried out inclusively, recognizing and protecting the communal rights of indigenous communities. This is crucial to ensure cultural sustainability, equitable distribution of benefits, and strengthening the position of indigenous communities in the local economic system. Traditional intellectual property protection schemes are a strategic instrument that can provide both a legal and moral basis for culture-based innovation.

IV. CONCLUSION

This research demonstrates that integrating appropriate technology design and local cultural values is a strategic and relevant approach to developing sago processing technology for the indigenous communities of Merauke. Technical tests of the sago processing machine demonstrate high production efficiency with low operational costs, while simultaneously addressing the need for increased productivity without sacrificing the social structure and cultural significance of traditional sago processing practices.

Socio-cultural data and focus group discussions (FGDs) demonstrate that technology acceptance is closely related to the extent to which the tool respects and supports local cultural practices. The significant positive correlation between cultural values and technology acceptance indicates that the sustainability of an innovation is largely determined by sensitivity to the social context of indigenous communities.

Economically, the use of the machine offers significant profit margins and can provide new livelihoods when managed collectively. A customary group-based investment scheme and benefit-sharing management are ideal approaches within the context of collective rights to local technology.

Legally, this research underscores the importance of recognizing indigenous communities' communal rights to local knowledge-based technology. Currently, there is no fully adequate national regulatory mechanism, but opportunities for protection through geographical indications, traditional cultural expressions, and community protocols can serve as a basis for policy strengthening.

Thus, the sago processing technology developed in this research is not merely a technical solution but also part of a cultural, economic, and legal empowerment strategy for indigenous communities. This model can be replicated for other local technologies across Indonesia, based on participatory, community-based principles and upholding cultural justice.

Recommendations based on the research findings:

1. Strengthening customary institutions as holders of communal rights to local technology needs to be facilitated through regulations and ongoing legal assistance.
2. Legal protection for local culture-based sago processing technology must be immediately pursued through the registration of geographical indications and documentation of traditional cultural expressions.
3. Appropriate technology designs should be developed with participatory involvement of indigenous communities to ensure social acceptance and sustainable use.
4. Local governments and research institutions are advised to promote benefit-sharing schemes and limited licensing for the use of local technology so that indigenous communities receive equitable economic benefits.

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