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SIXTY YEARS OF TROPICAL FORESTRY SCIENCE AT GADJAH MADA UNIVERSITY: A SCOPUS-BASED BIBLIOMETRIC STUDY

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SIXTY YEARS OF TROPICAL FORESTRY SCIENCE AT GADJAH MADA UNIVERSITY: A SCOPUS-BASED BIBLIOMETRIC STUDY. This Study undertakes a comprehensive bibliometric analysis to explore the research trends in the Scopus publications affiliated with the Faculty of Forestry at Gadjah Mada University (FF-UGM) in the generation of knowledge in tropical forestry. A total of 725 publications affiliated with FF-UGM were mined from the Scopus database and analyzed using VOSviewer and CiteSpace. The findings indicate a steady growth in the number of research publications and therefore, the cumulative count of 5,409 citations amounts to an average of 7.5 citations per publication. Furthermore, FF-UGM has engaged collaborations with researchers from all continents, with Japan exhibiting the highest network power through 112 collaborations. In relation to the sources of funding, a total of 518 articles has been granted financial assistance from 159 donors on a global scale, with 133 publications being self-sponsored by UGM. The Burst analysis, further, reveals emerging research frontiers to be explored further in future study including deforestation, catchments, agroforestry, and sustainable development. Thematic clustering indicates five big areas with high interdisciplinary approach to forest management, policy, product innovation, silviculture, and biodiversity conservation. The present bibliometric analysis proves that the FF-UGM is also changing its areas of interest into sustainable tropical forest ecosystems and serves as a source of both science and policy-related studies.

Keywords: Research trends, Faculty of Forestry, Gadjah Mada University, Scopus, tropical forestry

ENAM PULUH TAHUN ILMU KEHUTANAN TROPIS DI UNIVERSITAS GADJAH MADA: STUDI BIBLIOMETRIK BERBASIS SCOPUS. Studi ini melakukan analisis bibliometrik komprehensif untuk mengeksplorasi tren penelitian dalam publikasi Scopus yang berafiliasi dengan Fakultas Kehutanan Universitas Gadjah Mada (FF-UGM) dalam menghasilkan pengetahuan di bidang kehutanan tropis. Sebanyak 725 publikasi yang berafiliasi dengan FF-UGM ditelusuri dari database Scopus dan kemudian dianalisis menggunakan VOSviewer dan CiteSpace. Temuan tersebut menunjukkan pertumbuhan yang stabil dalam jumlah publikasi penelitian dan oleh karena itu, jumlah kumulatif 5.409 sitasi setara dengan rata-rata 7,5 sitasi per publikasi. Selain itu, FF-UGM telah berkolaborasi dengan peneliti dari semua benua, dengan Jepang menunjukkan kekuatan jaringan tertinggi melalui 112 kolaborasi. Terkait dengan sumber pendanaan, total 518 artikel telah mendapat bantuan keuangan dari 159 donor secara global, dengan 133 publikasi dibiayai sendiri oleh UGM. Analisis Burst lebih lanjut mengungkapkan bidang penelitian baru yang perlu dieksplorasi lebih lanjut dalam studi mendatang, termasuk deforestasi, daerah aliran sungai, agroforestri, dan pembangunan berkelanjutan. Pengelompokan tematik menunjukkan lima area besar dengan pendekatan interdisipliner yang tinggi terhadap pengelolaan hutan, kebijakan, inovasi produk, silvikultur, dan konservasi keanekaragaman hayati. Analisis bibliometrik ini membuktikan bahwa FF-UGM juga mengubah area minatnya menjadi ekosistem hutan tropis berkelanjutan dan berfungsi sebagai sumber studi yang berkaitan dengan sains dan kebijakan.

Kata kunci: Tren penelitian, Fakultas kehutanan, Universitas Gadjah Mada, Scopus, Kehutanan tropis

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I. INTRODUCTION

The major aim of tropical forestry studies is to achieve sustainable forest management and sustainable development (Poorter et al., 2021). This involves the need to understand the intricate ecological regimes within the tropical forest, and how to respond to such issues as deforestation by maintaining sustainable land use practices, equitable sharing of economic gains, and protection of biodiversity. As it is discussed in the study by Elliott et al. (2023), a combination of field research, remote sensing, and modeling is important in the study of tropical forests. This interdisciplinary way is important in enlightening the policies and taking up measures that are very vital to the conservation of these invaluable ecosystems. It also provides the long-term sustainability of the tropical forests besides fulfilling the needs of the locals.

In the era of the fast development of science, the evaluation of academic outputs created in academic institutions has gained significant value, and bibliometric studies have become a crucial part of this evaluation (Tomaszewski, 2023). Established in 1949, Gadjah Mada University is widely recognized as one of the oldest institutions of higher education in Indonesia. A separation process within the Faculty of Agriculture was accomplished in the year 1963 leading to the creation of the Faculty of Forestry at Gadjah Mada University (FF-UGM). The FF-UGM has four distinct departments, devoted to the fields of forest resource conservation, forest management, silviculture, and forest product technology. The departments mentioned above work together to achieve synergistic development of their common goal of pushing the limits of knowledge, technology, and efficient management of tropical forest ecosystems.

During the six decades of its existence, the FF-UGM has gained a lot of credit concerning its fearless pursuit of high standards of achievement. According to the UGM annual report (2021) highlights the substantial contribution of the FF-UGM in promoting progress in the fields of forestry and environmental sciences. It has recognized the growing importance of learning the emerging trends in research and the resultant implication that has followed. The relevance of the problem to the field of academia has been extended to include policymakers, high-profile academics and numerous stakeholders fully involved in the complex areas of forestry and environmental conservation to develop a sustainable development. (Stupnisky et al., 2019).

Numerous studies have been undertaken on a global scale to investigate the academic publications of institutions, organizations, and specific disciplines. The studies use several well-known sources including, such as Scopus, Web of Science (WOS), Elsevier, Science Direct, EBSCO, JSTOR, and ProQuest, among others (Shi et al., 2021). This study uses Scopus as a popular and widely used citation resource that consists of a database of abstracts of peer-reviewed academic literature (Vengadesh et al., 2023).

Bibliometric studies, based on data from extensive databases, have become a necessary method of determining the qualitative and quantitative output and impact of a specific topic or research center on the basis of analyzing publications (Hakim et al., 2022). It is done through defining key research areas and themes, monitoring citation patterns, and acknowledging the international collaborative activities (Klapka & Slaby, 2018). Given the prominent status of FF-UGM within the academic landscape of Indonesia, there is a strong need to subject it to comprehensive scrutiny in order to clarify its academic achievements and its contribution to the overall scientific community.

The purpose of this bibliometric research is to analyze the research products of FF-UGM in Scopus data, by developing a thorough review of the scientific impact of the faculty. This was done by carefully scrutinizing scholarly publications, citations, patterns of authorship, and the extent of international collaborations.

Furthermore, this study also identifies emerging research trends and areas of expertise, with an investment in the 60-year legacy of FF-UGM as an autonomous faculty within Gadjah Mada University.

The understanding of the complex research dynamics in the FF-UGM is important because it is not only essential to the clarification of academic objectives, but also to the creation of research-based policies and sustainable practices in scientific disciplines forestry and environmental science. With this investigation going on, it can possibly fill the existing gap in the field of bibliometrics and give priceless information on the current state of research in this prestigious institution.

II. MATERIAL AND METHOD

A. Data Collection

The affiliated publication records at FF-UGM were downloaded from Scopus, a leading abstract and citation database popular in the scientific community. A strict data mining process was followed in order to guarantee the accuracy and quality of the selected documents. The first step consisted of conducting a thorough search using specific keywords associated with FF-UGM: [AFFIL (faculty AND of AND forestry) OR AFFIL (fakultas AND kehutanan) AND AFFIL (universitas AND gadjah AND mada) OR AFFIL (university AND gadjah AND mada) OR AFFIL (gadjah AND mada)]. This involved different spellings of the name of the institution both in the English and Indonesian languages, to capture all the possible spellings of the institution. There was no time limitation to capture all publications affiliated with FF-UGM from its inception until September 2023.

We then further reduced our scope of interest to four major types of documents that include conference papers and scientific articles, book chapters, and reviews. The usage of this classification system allowed including a wide variety of materials and promoted the deep knowledge of the subject in question. Language consistency was also another criterion which was taken into consideration when selecting the document. Only publications that were written mostly in English were included in order to bring about clarity and ease the further analysis.

After applying these strict selection criteria, we were able to come up with a final dataset comprising 725 publications. The following overall analysis performed in this paper is based on this dataset.

B. Methods

Two of the most prominent bibliometric analysis tools were tapped in this research. The first tool, CiteSpace, is widely recognized as a leading software application with a specific purpose to analyze literature data in details. CiteSpace is a software that is specifically developed for the purpose of investigating the organization and distribution of scientific knowledge (Chen & Song, 2019). It makes use of scientific metrology, information visualization and data analysis methods. Researchers are provided with the ability to create a wide range of knowledge graphs, which serve as visual depictions of the complex network of citations found inside academic literature (Chen, 2014; 2020) In this study, we employed CiteSpace 6.2.R4 (64-bit) Basic version.

The second tool engaged in this study is VOSviewer, a software application developed using the Java programming language. VOSviewer is a flexible tool that can be used to build and visualize network-based maps. It simplifies the process of exploration and analysis of these maps, which helps to gain a better insight into the intricate interrelations inherent in the dataset (van Eck & Waltman, 2023). In this study, VOSviewer 1.6.19 with Java 1.8.0_371 was deployed for the purpose of conducting our investigation.

The utilization of advanced analysis instruments has contributed to the acquisition of useful insights and have also enabled the generation of clear visual representations that explain the scientific literature landscape of FF-UGM.

III. RESULT AND DISCUSSION

A. Result

Overview of FF-UGM Research Outputs

Publication and Citation Quantities

Figure 1 shows the temporal trend of annual publication volume and cumulative citations of the Faculty of Forestry at Gadjah Mada University (FF-UGM) since its inception. The dataset obtained from Scopus includes a total of 725 publications and can be divided into 532 articles, 161 conference papers, 18 book chapters, and 14 reviews.

The publications of FF-UGM in the Scopus database have exhibited a steady and continuous growth since its inception in 1963. The initial publication affiliated to FF-UGM in Scopus dates back to 1988 and was followed by another publication in 1997. However, it was only in 2003 that the research production of FF-UGM began to exhibit a consistent upward trend, ultimately culminating in a pinnacle of 131 articles in 2022. As of September 15, 2023, the date of data mining, the FF-UGM portfolio comprises a cumulative count of 725 research articles. The observed surge in publications implies the possible increase in the number of existing resources, including financial, technological, and human resources, as well as improvement in the knowledge and abilities of the faculty. A combination of this factor helps in motivation of FF-UGM in attaining its aspirations of becoming a nationally renowned internationally recognized institution in the field of tropical forestry. The venture is guided by the principles of Pancasila and devoted towards developing the well-being of the country.

This review singles out two landmark events in the history of the research publications of FF-UGM. In 2016, FF-UGM achieved the significant milestone of surpassing 20 annual publications for the first time. In 2020, FF-UGM accomplished a significant achievement by exceeding a total of 120 publications within a single year. Before 2016, the annual publication count of FF-UGM constantly stayed below 20. The publications have grown by a great margin of 64.3% within the period between 2016 and 2020 with 34 publications in 2016, and 124 publications in 2020. This growth accounted for 45% of the total 725 publications that were recorded since 1988.

Cumulative trends in frequency of citation with time are also shown in figure 1. Between 1988 and 2023, the works of FF-UGM had a total of 5,409 citations in the cumulative years. The average number of citations per year is 154, which corresponds approximately to 7.5 citations per publication. Remarkably, the number of citations to the publications of FF-

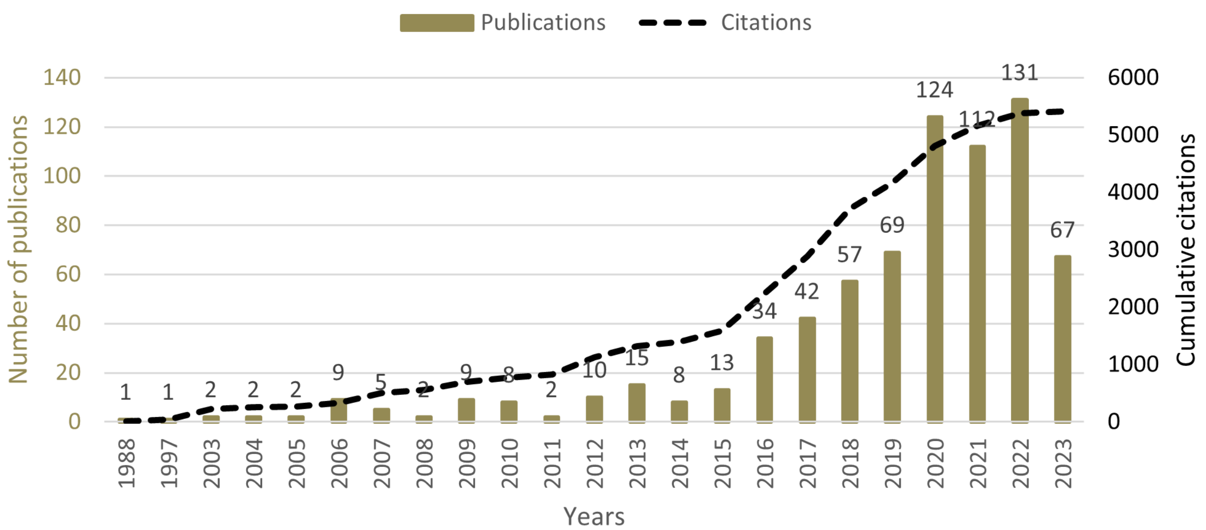

Figure 1. Evolution of Scopus' Publications and Citations Affiliated with FF-UGM

UGM also increased significantly throughout the years 2016-2020. The mean annual amount of volume of citation was 643. Furthermore, our analysis has revealed a strong positive connection of 0.53 between the number of published works and the number of citations received. The correlation witnessed shows that the self-citation among the researchers of FF-UGM is of high nature. This means that their natural quality and influence of their respective publications might have very minimal influence on the chances of receiving citations.

The subject categories of publications

Within the realm of subject categorization in academic publications, it becomes evident that research conducted at FF-UGM has exhibited a tendency to surpass disciplinary confines throughout the course of the last three and a half decades. This has resulted in the generation of academic materials that cover a broad spectrum of 23 distinct subject areas. Figure 2 s a detailed description of the different subject areas that will be covered in this scholarly undertaking. One of the prominent areas of the corpus is Agricultural and Biological Sciences as it is a substantial part, containing 413 publications, which constitute 29.3% of the entire corpus.

In addition, it can be noted that the discipline of Environmental Science has a notable presence, accounting for 345 papers (24.5%). Immediately after this is the group of Biochemistry, Genetics, and Molecular Biology which adds up to 142 publications 142 publications (10.1%). The field of Earth and Planetary Sciences is also a substantial entity with 140 papers (9.9%). The other important fields of interest include Social Science, accounting for 7.0% of the total, Material Science with a contribution of 4.5%, Engineering with a share of 3.4%, Economics, Econometrics, and Finance collectively representing 2.0%, Energy making up 1.5%, and Chemical Engineering contributing 1.3%. Furthermore, it is worth mentioning that there exists a significant presence within the wider scope of 'other topic fields,' which makes a contribution of 6.5% to the entire body of scholarly work.

This spread in the wide fields of study provides invaluable information in the multidisciplinary approach needed to overcome the multifaceted challenge of the four departments of the faculty, namely: Conservation of Forest Resources, Forest Management, Silviculture, and Forest

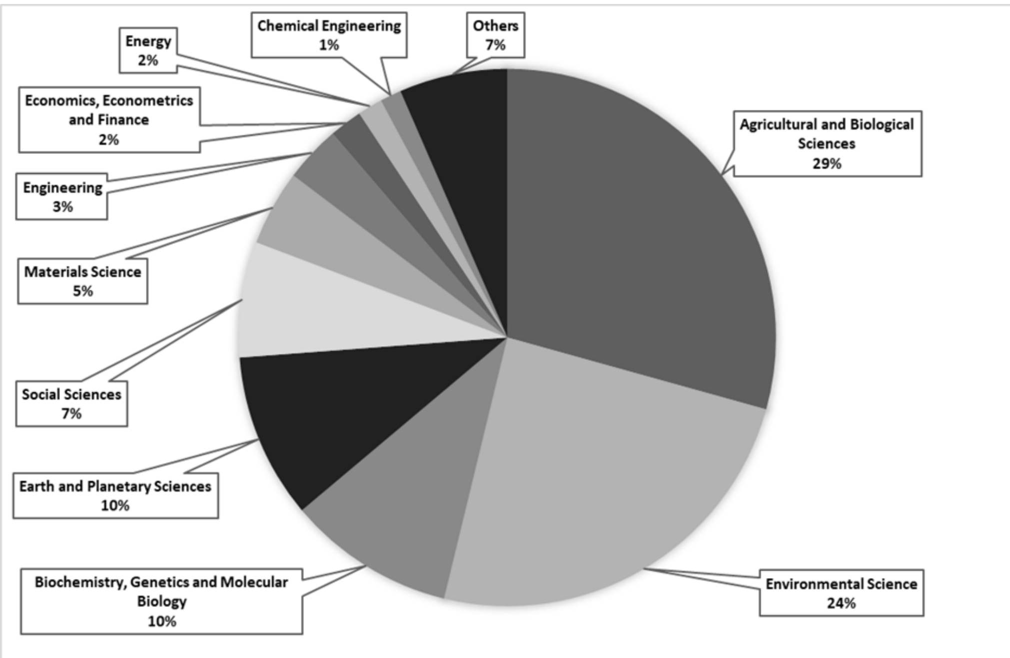

Figure 2. Subject area of FF-UGM's research outputs.

Product Technology. The collective attempts to derive the ecological and biological dynamics of depletion of tropical forests are indicated by the vast amount of literature in the fields of agricultural and biological sciences, as well as environmental science. Furthermore, the active involvement in the field of earth and planetary sciences indicates a growing fascination with exploring the ecological consequences and dynamics of earth's systems that are associated with the decline of tropical forests.

Furthermore, the role of Social Science in the situation indicates that the socio-economic and political nature, the intricate connection of human activity with forest management are considered, and the implications of these issues on human well-being can be observed. It's essential to emphasize that the quantity of publications in each subject area serves as a reflection of research volume and is not necessarily an indicator of research quality or impact.

Most cited publications

Within the pool of 725 publications affiliated to FF-UGM, a noteworthy 541 (75%), have garnered at least one citation by September 2023. It is worth noting that 189 publications or 26% of them have surpassed average citation of 7.5 with a minimum of 8 citation. Moreover, an even smaller number of 68 publications, which constitute (9%), have been able to achieve a respectable minimum of 20 citations.

Table 1 provides the list of the most influential publications that are related to the FF-UGM within the Scopus database. These publications are characterized by their attainment of the highest citation counts (more than 50 citations).

Table 1. Top publications affiliated with FF-UGM

No	Authors and year of publication	Title	Journal	TC
Department of Silviculture				
1	Jones D. T., Susilo F. X., Bignell D. E., Hardiwinoto S., Gillison A. N., & Eggleton P. (2003)	Termite assemblage collapse along a land-use intensification gradient in lowland central Sumatra, Indonesia	Journal of Applied Ecology	179
2	Beukema H., Danielsen F., Vincent G., Hardiwinoto S., & Van Andel J. (2007)	Plant and bird diversity in rubber agroforests in the lowlands of Sumatra, Indonesia	Agroforestry Systems	110
3	Harwood C. E., Hardiyanto E. B., & Yong W. C. (2015)	Genetic improvement of tropical acacias: achievements and challenges	Southern Forest	40
4	Begum S., Kudo K., Rahman M. H., Nakaba S., Yamagishi Y., Nabeshima E., Nugroho W. D., Oribe Y., Kitin P., Jin H.-O., & Funada R. (2018)	Climate change and the regulation of wood formation in trees by temperature	Trees - Structure and Function	62
Department of Forest Management				
1	Maryudi A., Devkota R. R., Schusser C., Yufanyi C., Salla M., Aurenhammer H., Rotchanaphatharawit R., & Krott M. (2012)	Back to basics: Considerations in evaluating the outcomes of community forestry	Forest Policy and Economics	137
2	Sahide M. A. K., Supratman S., Maryudi A., Kim Y.-S., & Giessen L. (2016)	Decentralization Policy as Recentralization Strategy: Forest Management Units and Community Forestry in Indonesia	International Forestry Review	95
3	Prabowo D., Maryudi A., & Imron M. A. (2017)	Conversion of forests into oil palm plantations in West Kalimantan, Indonesia: Insights from actors' power and its dynamics	Forest Policy and Economics	61
4	Maryudi A., Citraningtyas E. R., Purwanto R. H., Sadono R., Suryanto P., Riyanto S., & Siswoko B. D. (2016)	The emerging power of peasant farmers in the tenurial conflicts over the uses of state forestland in Central Java, Indonesia	Forest Policy and Economics	42
Departement of Forest Resource Conservation				
1	Marhaento H., Booij M. J., & Hoekstra A. Y. (2018)	Hydrological response to future land-use changes and climate change in a tropical catchment	Hydrological Sciences Journal	86
2	Nijman V., Langgeng A., Birot H., Imron M. A., & Nekaris K. A. I. (2018)	Wildlife trade, captive breeding, and the imminent extinction of a songbird	Global Ecology and Conservation	42

No	Authors and year of publication	Title	Journal	TC
3	Pudyatmoko, S. (2017)	Free-ranging livestock influence species richness, occupancy, and daily behavior of wild mammalian species in Baluran National Park, Indonesia	Mammalian Biology	35
Departement of Forest Product Technology				
1	Schollaen K., Heinrich I., Neuwirth B., Krusic P. J., D'Arrigo R. D., Karyanto O., & Helle G. (2013)	Multiple tree-ring chronologies (ring width, δ13C and δ18O) reveal dry and rainy season signals of rainfall in Indonesia	Quaternary Science Reviews	74
2	Nugroho W. D., Marsoem S. N., Yasue K., Fujiwara T., Nakajima T., Hayakawa M., Nakaba S., Yamagishi Y., Jin H.-O., Kubo, T., & Funada R. (2012)	Radial variations in the anatomical characteristics and density of the wood of *Acacia mangium* of five different provenances in Indonesia	Journal of Wood Science	47
3	Widyorini R., Nugraha P. A., Rahman M. Z. A., & Prayitno T. A. (2016)	Bonding ability of a new adhesive composed of citric acid-sucrose for particleboard	BioResources	40
4	Lukmandaru G., & Takahashi K. (2009)	Radial distribution of quinones in plantation teak (*Tectona grandis* L.f.)	Annals of Forest Science	38

TC: total citation counts of each publication

Collaboration and Networking Analysis

Country Networking

The research publications affiliated with FF-UGM on Scopus have exhibited collaboration with scholars from a wide array of backgrounds, encompassing 80 nations across all continents. Figure 3, which shows a distribution map, is the global coverage of FF-UGM collaborative research activity.

The collaborative network that was created between countries that are involved in FF-UGM research publications is visually described in figure 4. This figure includes only nations that have collaborated in at least five publications. In this context, every country is depicted as a node, wherein the size of each node is directly proportional to the quantity of publications attributed to that country. The thickness of the lines linking nodes represents the degree of strength of the co-authorship links among these countries. The countries are categorized into four distinct clusters, distinguished by different colors.

Table 2 provides a comprehensive breakdown of each country and cluster (a group of similar countries occurring closely together), encompassing a range of key metrics. These metrics include the number of publications (P), the percentage of country publications

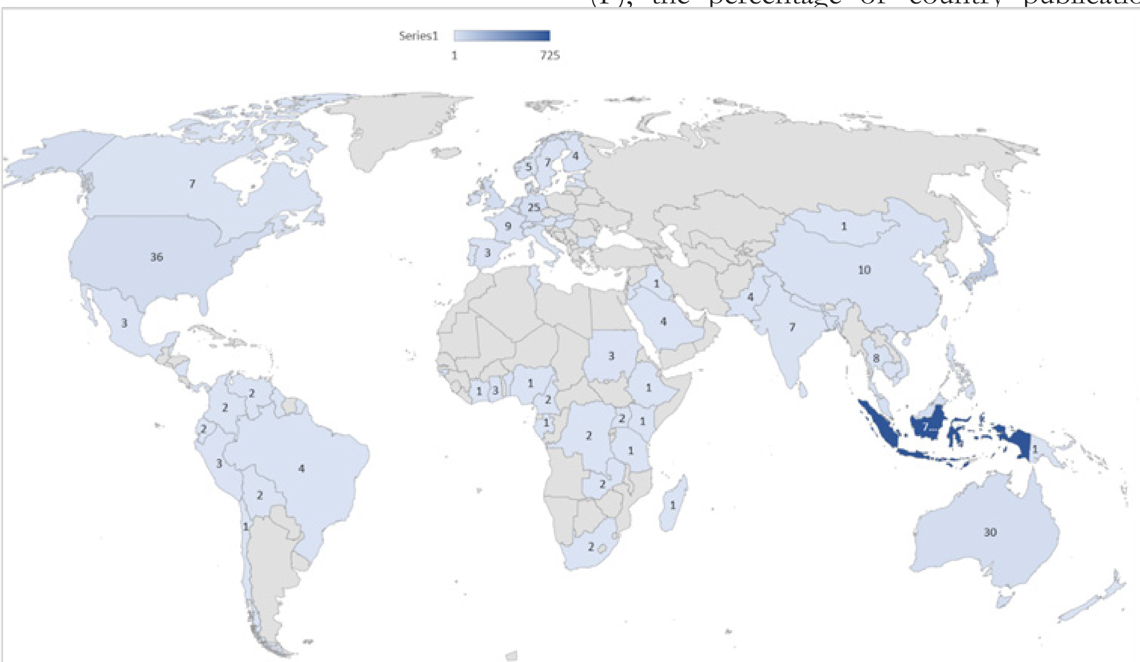

Figure 3. Distribution map of the countries' collaboration in FF-UGM research

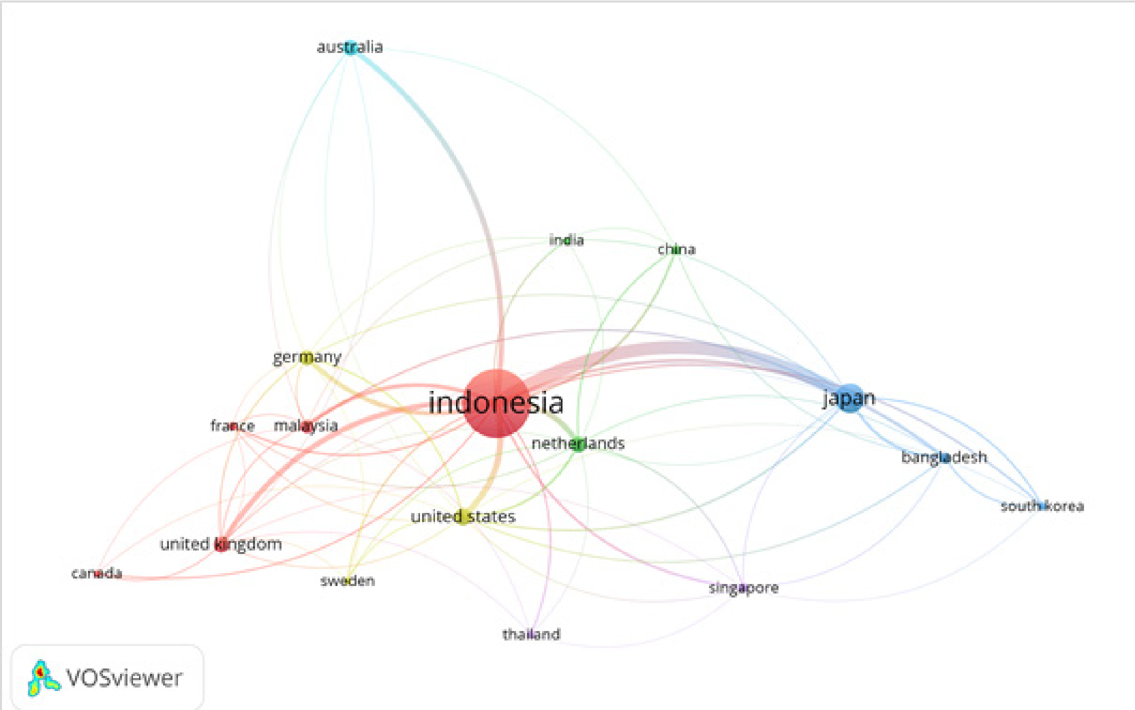

Figure 4. Distribution map of the countries' collaboration in FF-UGM research

relative to the total of 725 research outputs (%725), total citations (TC), average citations per publication (TC/P), normalized citation (N.C), the count of links with other countries, the cumulative strength of these links (TLS), and the corresponding cluster number.

Naturally, Indonesia leads in the number of publications (725) because all publications are affiliated with FF-UGM. Japan appears as the first partner country with collaboration on 112 publications and the percentage of total contributions (15%), indicating its significant involvement in this field, working together with FF-UGM. However, when considering publication impact, Japan, the United States, Germany, and the United Kingdom emerge as highly efficient, with a relatively high total citation count (TC) higher than 600. The countries such as Singapore, India and South Korea have moderate figures on publications and have more average citation per publication (TC/P), which also reflects the quality and impact of their studies. This wide range of contributions by various countries highlights how the world is interested and working together in the field of tropical forestry research and each country delivers individual and valuable inputs towards the discipline.

Table 2. List of countries sharing at least 5 common publications with the FF-UGM

Country	P	%725	TC	TC/P	N.C	Links	TLS	Cluster
Indonesia	725	100	5140	7.14	718.70	16	331	1
Japan	112	15.2	1071	9.74	101.37	10	148	3
United States	34	4.7	711	20.91	73.21	12	72	4
Australia	30	4.0	563	20.11	39.87	6	33	5
Netherlands	28	3.9	575	20.54	55.10	11	56	2
United Kingdom	28	3.9	607	21.68	86.03	12	47	1
Germany	23	3.2	671	29.17	51.59	9	42	4
Malaysia	18	2.5	353	19.61	18.57	9	36	1
Bangladesh	13	1.8	227	17.46	20.67	7	39	3
Singapore	9	1.2	321	35.67	32.47	8	22	3

Country	P	%725	TC	TC/P	N.C	Links	TLS	Cluster
China	8	1.1	50	6.25	10.84	5	17	2
France	7	1.0	128	18.28	5.68	6	15	1
South Korea	7	1.0	211	30.14	11.35	5	20	3
Thailand	6	0.8	44	7.33	9.51	5	10	3
Canada	5	0.7	56	11.2	4.33	4	10	1
India	5	0.7	174	34.8	7.47	6	10	2
Sweden	5	0.7	112	22.4	13.95	5	12	4

P: number of publications of a country related to coauthorship with FF-UGM researchers. %/725: percentage of the country's publications out of a total of 725 FF-UGM's publications. TC: total citations of a country. TC/P: average citations per publication of a country. N.C: normalized number of citations received by a country. TLS: total link strength of a country.

The network of collaborative partnerships among institutions

Our list of 752 publications has 159 places of collaboration with the FF-UGM. Table 3 shows a summary of the institutions that have been very productive in terms of coauthoring at least 21 works in partnership with FF-UGM. It is interesting to note that among the top nine mentioned institutions only academic institutions of Indonesia and Japan were listed and this shows that FF-UGM is national based and has good ties with Japanese universities. In terms of scientific collaboration, it is noteworthy that Institut Pertanian Bogor (IPB) University has become the leading institution as it has been involved in 36 collaborations with FF-UGM. The Tokyo University of Agriculture and Technology has actively participated in 31 collaboration initiatives with FF-UGM.

Table 3. Top prolific collaborative institutions

Institution	P	Country
IPB University	36	Indonesia
Tokyo University of Agriculture and Technology	31	Japan
Institut Teknologi Bandung	30	Indonesia
Badan Riset dan Inovasi Nasional	26	Indonesia
Universitas Airlangga	25	Indonesia
Hasanuddin University	24	Indonesia
Forestry and Forest Products Research Institute	23	Japan
Kyoto University	21	Japan
Universitas Sumatera Utara	21	Indonesia

P: number of publications of each institution coauthored with FF-UGM researchers

Source of Research Funding

Among the 725 articles that were examined, a notable portion of 518 publications (71%), have received funding from a wide-ranging group of 159 donors from several continents. These sponsors encompass a diverse range of categories, including universities (such as UGM, Hasanuddin University, University of Western Australia, IPB University, King Saud University, Kyushu University, among others), Indonesian Ministries (such as the Ministry of Education, Culture, Sports, Science and Technology; Ministry of Environment and Forestry (KLHK); Ministry of Finance; Ministry of Foreign affairs), Foreign Ministries (Ministry of Science and Technology, Taiwan; Ministry of the Environment, Japan; Ministry of Higher Education, Egypt), foreign country development agencies (including the United States Agency for International Development, Norwegian Agency for Development Cooperation, Australian Agency for International Development), international organizations (such as the European Research Council, International Fund for Agricultural Development, UNDP, UNESCO, CGIAR, WWF), and grants awarded through competitive selection processes (such as the Mohamed bin Zayed Species Conservation Fund, Leverhulme Trust, Arcus Foundation, Forest Conservation Fund). Table 4 presents a comprehensive overview of the leading 20 funding institutions for FF-UGM research, together with their corresponding countries of origin.

Table 4. Funding institutions supporting FF-UGM's research.

	Institution	P	Country/Territory
1	Universitas Gadjah Mada	133	Indonesia
2	Ministry of Education, Culture, Sports, Science and Technology	69	Indonesia
3	Japan Society for the Promotion of Science	26	Japan
4	Lembaga Pengelola Dana Pendidikan	14	Indonesia
5	Australian Centre for International Agricultural Research	13	Australia
6	Ministry of Environment and Forestry	11	Indonesia
7	Direktorat Jenderal Pendidikan Tinggi	9	Indonesia
8	Ministry of Finance	9	Indonesia
9	Japan Student Services Organization	7	Japan
10	United States Agency for International Development	7	USA
11	Cleveland Zoological Society	6	USA
12	Institut Teknologi Bandung	6	Indonesia
13	Margot Marsh Biodiversity Foundation	6	USA
14	National Geographic Society	5	USA
15	Universitas Airlangga	5	Indonesia
16	Wellcome Trust	5	UK
17	Columbus Zoo and Aquarium	4	USA
18	Direktoratet for Utviklingssamarbeid	4	Norway
19	Disney Worldwide Conservation Fund	4	USA
20	European Commission / European Research Council	4	Europe

P: number of publications sponsored by each funding institution

It is interesting to note that, the Indonesian institutions lead in the number of publications among the top 20 sponsors. It is worth mentioning that the Gadjah Mada University (UGM) has self-funded a total of 133 publications. This observation highlights the importance of developing nations investing in the promotion of research projects by them, consistent with previous research (Nanda et al., 2021; Sills & Sanganyado, 2021). This way, they are able to solve problems that are applicable to their situation and minimize chances of being subjected to influence of the research priorities and interests of countries that fund the research.

FF-UGM's Research Themes Analysis

Keyworks evolution

Figure 5 Figure 5 offers clues concerning the historical evolution of the research interests of FF-UGM, which is presented in the form of a word cloud created due to the presence of terms used in its publications. The given picture shows the correlation between the size of words and the rate of their occurrence in which the bigger words will be used to reflect the bigger frequency.

Before 2009, the primary research focus of FF-UGM was centered on many aspects including Acacia plantation study in Southeast Asia, Eurasia, and Indonesia. Additionally, investigations pertaining to plant growth, density, species genetic identification using DNA analysis, and forest management were conducted (Kurinobu et al., 2006). Between 2009 and 2013, a trend of the investigation of silviculture with the focus on cultivation of Eucalyptus as a primary species of interest can be observed. During this time, there was a notable surge in research conducted in the fields of wood products and biodiversity protection. Furthermore, following the 13th Conference of the Parties (COP) in Bali and the creation of the REDD mechanism, FF-UGM also engaged in research activities related to the forest biomass and its carbon sequestration potential (Wirabuana et al., 2020).

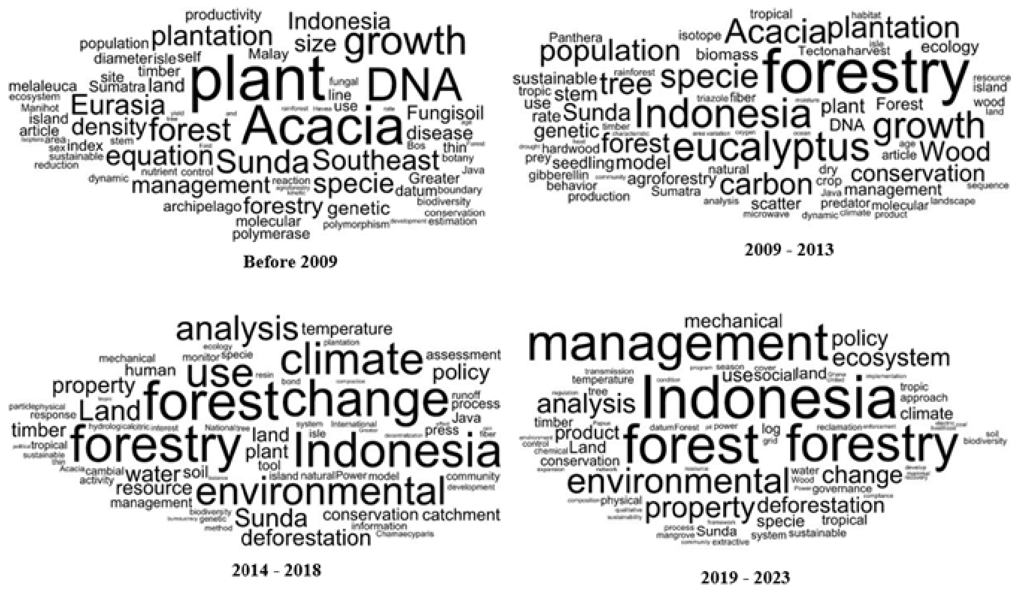

Figure 5. Temporal Dynamics of FF-UGM Research Keywords

Before 2009, the primary research focus of FF-UGM was centered on many aspects including Acacia plantation study in Southeast Asia, Eurasia, and Indonesia. Additionally, investigations pertaining to plant growth, density, species genetic identification using DNA analysis, and forest management were conducted (Kurinobu et al., 2006). Between 2009 and 2013, a trend of the investigation of silviculture with the focus on cultivation of Eucalyptus as a primary species of interest can be observed. During this time, there was a notable surge in research conducted in the fields of wood products and biodiversity protection. Furthermore, following the 13th Conference of the Parties (COP) in Bali and the creation of the REDD mechanism, FF-UGM also engaged in research activities related to the forest biomass and its carbon sequestration potential (Wirabuana et al., 2020).

In the years 2014 to 2018, much attention in the FF-UGM community was strongly concerned with the issue of climate change. It included the in-depth analysis of the land use change and deforestation along with the respective impacts on environmental sustainability. These impacts touched on a variety of dimensions, including temperature, the qualities of soil, water resources, and water catchment (Marhaento et al., 2018). Following the year 2018, there was a notable movement in the predominant research issues within the FF-UGM community towards the sustainable management of the environment. This entailed policy analysis (Rahayu et al., 2023) while exploring non-wood product qualities as potential alternatives to wood in the field of building (Sucipto et al., 2020).

Emerging and Prospective Area of Research Focus: Keywords with Burst

Burst keywords refer to terms that undergo a rapid increase in their usage frequency. To detect and make special interest such sudden rises in activity, researchers apply an extremely effective methodology of analysis known as burst detection. The methodology outlined by Chen (2014) is essential towards identifying the keywords that will draw significant attention to the keywords of the relevant scholarly communities in a given time frame. The keywords are of great relevance since they serve as significant pointers of research venturing and draw predictions on the direction of research to come. Figure 6 displays a combination of the top 17 bursting keywords that have been detected using the CiteSpace tool. This presentation provides an overview of the power and duration of the occurrences being discussed. This period is shown as a graph and the blue line illustrates the period. Besides, the red line on the graph shows the start and end times of each burst keyword (Chen, 2014).

The year 2003 had a notable surge in research activity focused on the principal term "Acacia mangium". During the period from 2006 to 2012, there were notable changes in the research emphasis, as seen by the emergence of "biomass," "Tectona grandis," "rainforest," and "Falcataria moluccana" as major and actively studied subjects.

The research interests have shifted significantly with a new set of keywords ever since 2015. Such terms include "runoff," "deforestation," "catchments," "agroforestry system," "sustainable development," and "agricultural robots," have become major fields of concern. One should admit that these issues remain open to be researched more and they demand additional research efforts. Thus, they act as promising fields of future research undertakings.

Word Occurrence

The clustering analysis of publication titles and abstracts, as depicted in Figure 7, has identified five primary clusters of research themes that correspond to the four departments of FF-UGM.

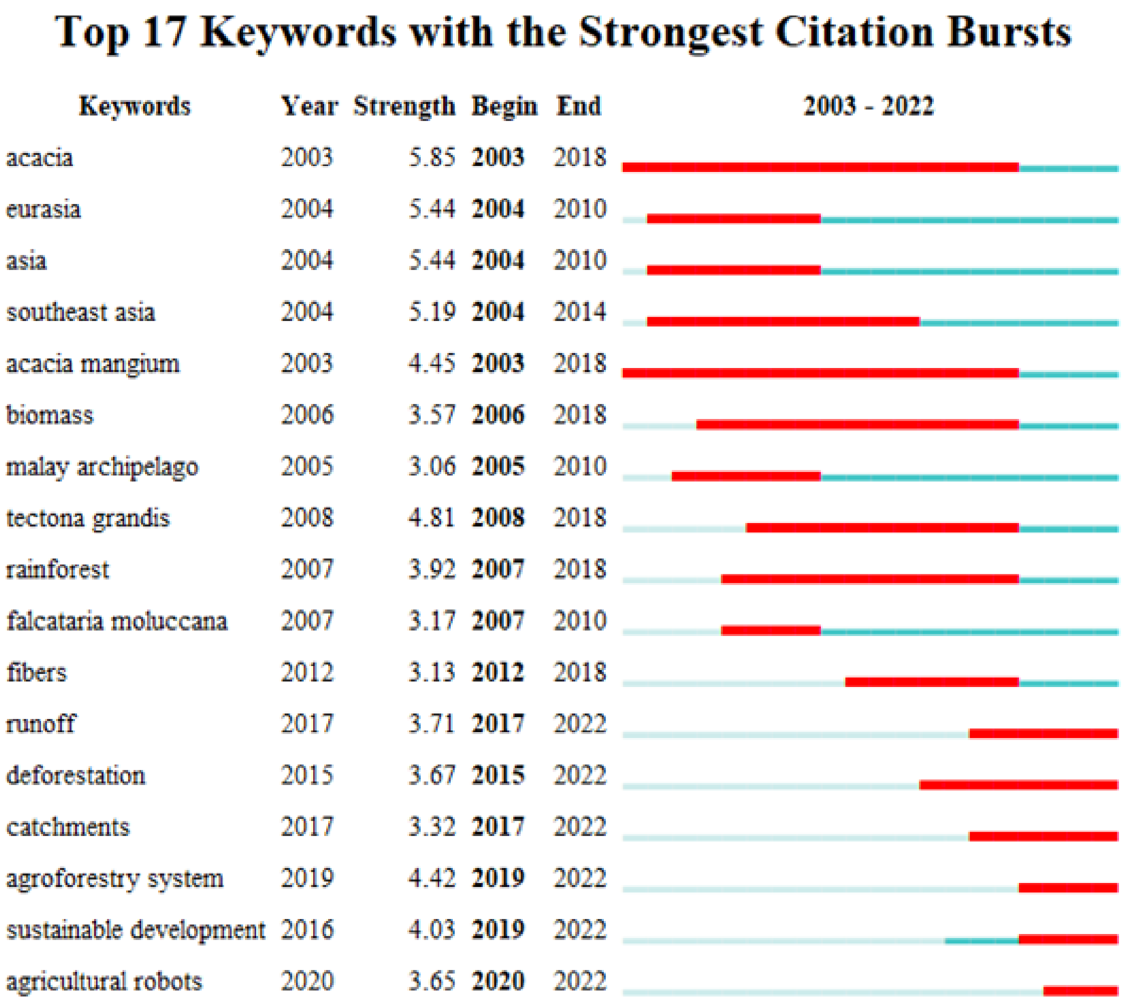

Figure 6. Keywords with bursts within FF-UGM Scopus publications

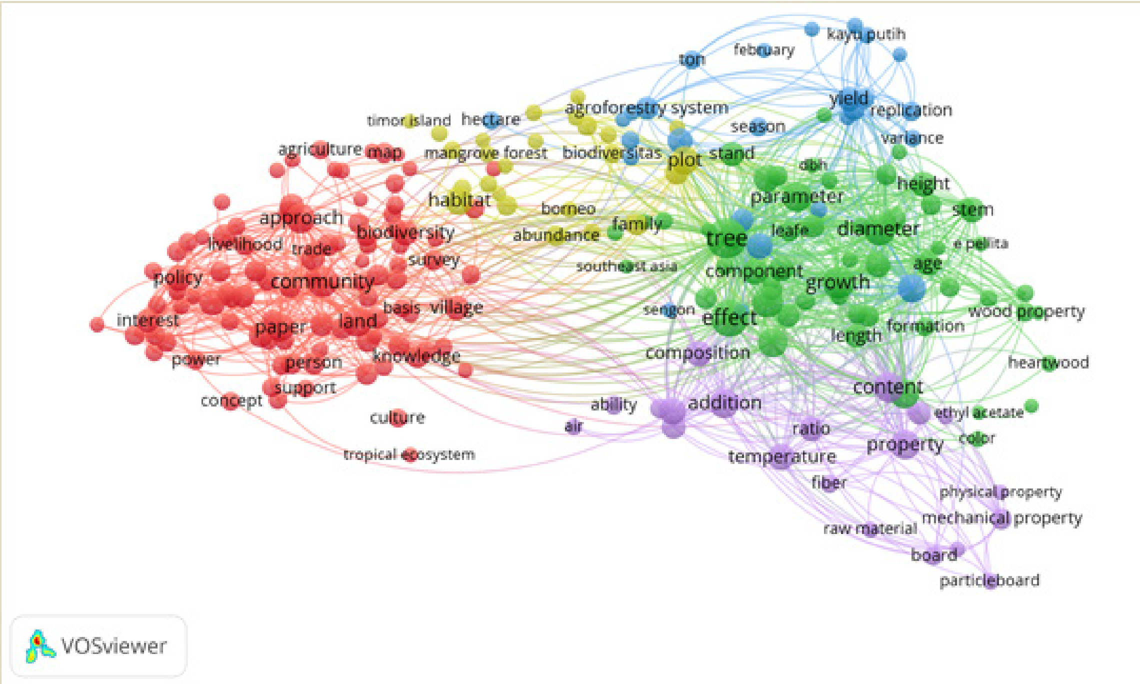

Figure 7. Visualization of the keywords' co-occurring clustering in FF-UGM research

B. Discussion

The research themes of FF-UGM naturally cut across the four departments of the faculty. The first and second clusters are associated with the Department of Forest Management of the FF-UGM. The first cluster under red color includes such words as "policy," "interest," "community," "land," "approach," "livelihood," "village," "power," "interview," "survey," "local community," "government," "farmer," "dynamic," "importance," and "challenge." The abovementioned terms comprise the most common questions and procedures that are frequently applied to the area of forest policy research which implies the set of guidelines and regulations according to which practices regarding the forest management are regulated. The establishment of the Research Center for Forest Policy and History Studies, known as "SEBIJAK Institute", is a response to the notable progress made in the field of forest policy and governance studies. This initiative is dedicated to the overall analysis of various subjects, including policy and power networks, governance, land tenure and access, community-based forest management, land use policy and politics, environmental justice, verification of legality, and sustainable forestry. Moreover, it is actively interested in developing new approaches that will improve the sphere of forest policy and governance studies.

The research center has conducted power network analysis of different stakeholders in forest management who include rural communities (Permadi et al., 2018), governmental agencies (Parera et al., 2022), and non-governmental organizations (Rahayu et al., 2023) within its activities; each has its own interests and viewpoints. Relative to land tenure and access, the research center has discovered a number of things that explain the low motivation of the local communities with the policy. These considerations provide an insight into particular barriers related to the approaches to access and the benefits that the local populations obtain due to the rights granted to them (Ragandhi et al., 2021). Additionally, researchers have noted that state institutions have a very important role to play in the forest tenure reform process (Rodd et al., 2022). They have also emphasized the need to develop appropriate land use policies and politics to have sustainable forest resource management (Nurprabowo et al., 2021).

The second cluster, represented by the green color, includes the terms such as "tree," "parameters," "characteristics," "height," "density," "sample," and "site." Their usage can be mostly found in the analysis and description of the characteristics of forests, which are crucial in developing efficient forest management strategies (Harahap et al., 2022). The management of forests requires careful collection and analysis of information on various features of the forest ecosystem. This includes the overall and accurate acquisition of details of information about the tree species, forests density, age structure, biodiversity, soil structure, climatic factors and anthropic factors.

The Department of Forest Management has utilized many approaches, including field surveys, remote sensing technologies, such as satellite images (Musthofa et al., 2022), and ecological modeling (Wibowo et al., 2023), in order to assess forest resources. The obtained data is then analyzed extensively to be able to understand the multifaceted interrelationships of the forest ecosystems, identify trends, and project future changes over a given period (Budiadi et al., 2023). The interpretation of a large amount of data is conducted with the help of advanced analytical methods, such as Geographic Information Systems (GIS) and statistical modeling. These techniques enable forest managers to make well-informed decisions (Marhaento, 2022). Constant monitoring and analysis is more important to the adjustment of management techniques following shifting environment and other human activities and global trends. This will provide sustainable use and conservation of forest resources (Dimyati et al., 2023).

Furthermore, the Department conducted an investigation into community-based forest management by evaluating the outcomes of community forestry programs (Maryudi et al., 2012). Moreover, the department also looked into the aspect of community forestry in improving the livelihoods of local communities (Yokota et al., 2014). In addition, an extensive literature has been conducted to study and investigate the processes that influence the changes in forest biomass and carbon stock (Alam et al., 2022). In discussing the problem of climate change, one should focus on the potentially significant contribution of forests to the forest incentive systems such as REDD+ and the possibilities of stakeholders to participate in the process (Bong, Felker, & Maryudi, 2016).

These thematic clusters are indicative of the variety of research questions and methods required to study the management of forests and focus on the role of foreign actors specifically (Nanda et al., 2022). The network of interconnected concepts presented here supports the importance of the discussion on forest policy development and governance approaches.

The third cluster, depicted in the color purple includes terms like "wood," "raw material," "fiber," "mechanical properties," "board," and "physical properties." These phrases hold significant relevance within the Department of Forest Product Technology at FF-UGM, as they are geared towards furthering the careers of science and technology so as to handle and process the wood and non-timber forest products. The end product is to improve the livelihood of the entire humanity. The earlier research on this specific area has put a heavy emphasis on the examination of physical and mechanical characteristics of wood, in particular, regarding tension, strength, density, and elasticity (Ngadianto et al., 2020).

In addition, to alleviate the strain on wood resources, various non-timber forest products, including snake fruit fiber (Darmanto et al., 2017), bamboo (Marsoem et al., 2015), elephant dung fiber (Widyorini et al., 2018), and Kenaf Fiber-Epoxy (Setyayunita et al., 2022), have been investigated as potential alternatives to wood in the manufacturing of furniture. Moreover, the sphere of technology related to the extraction and use of essential oils created by different species of forests also has been developed significantly (Umroni et al., 2021).

The fourth cluster, denoted in blue, encompasses terms like "plot," "cultivation," "soil," "experiment," "block," "replication," and "ton." The terms are widespread in terms of silviculture with the aim of scientific and technological advancement and the restoration of forests. This, on its part, helps to increase the productivity and benefits derived on the forest resources, which in the end benefits the welfare of the community. The study in the field of this specific issue involves a variety of factors related to the introduction of tree planting and ecosystem recovery (Nurjanto et al., 2023). Study of soil has paid attention to different issues including soil fertility, soil quality, soil properties, and how trees impact soil quality and composition (Sadono et al., 2021). Additionally, the occurrence of the terms "species kayu putih" and its corresponding scientific designation "*melaleuca cajuputi*" can be ascribed to the substantial research focus on this particular species conducted by the Department of Silviculture at FF-UGM (Suryanto et al., 2020). Several research investigates various agroforestry systems implemented throughout nations and emphasize their advantages and challenges of such systems to the sustainable forest management and the needs of the locals (Achmad et al., 2022).

The final cluster, represented in yellow, includes terms like "diversity," "composition," "habitat," "family," "abundance," "biodiversity," and "bird." The concepts mentioned above are often coupled with the Department of Biodiversity Conservation that is focused on scientific and technological advancement in the sphere of forest ecosystem conservation. The main goals of the department are preservation, protection, management and sustainable exploitation of forest resources with the purpose to provide their long-term sustainability as one of the main bases of life. These objectives align with the research priorities of the Forest Resource Conservation department at FF-UGM, as outlined by Poor et al. (2021). Research in the given area specifically puts the focus on the evaluation of the threat to biodiversity, such as logging and the expansion of agricultural land (Hemida et al., 2022) that have been known to cause habitat fragmentation. Moreover, academic research enlightened the importance of agroforestry (Ridho et al., 2023) in the preservation of biodiversity levels, and the essential role of the protected areas management (Meilani et al., 2019).

Limitations of the study

Although the given study provides an elaborate and in-depth analysis of trends and ideas, it is imperative to note that tendencies in the sector are subject to change and liable to significant changes in the future. Consequently, we anticipate variations in co-authorship and citation results, particularly as more recent articles are likely to accrue higher citation rates. It is reasonable to suppose that not all of the outstanding writers could be accurately missed by leading researchers when performing the citation analysis and research study. Additionally, it is important to note that this bibliometric study is limited to a single database Scopus. This will be used to enrich the future research efforts and to have a more holistic view of FF-UGM research patterns.

IV. CONCLUSION

In light of the foregoing discussion, it is clear that the Faculty of Forestry of Gadjah Mada University (FF-UGM) has significant strengths in a variety of key areas that lie within the scope of the forestry studies. It is important to note that, although the number of the outputs in terms of the number of publications and citations is promising given the recent trends, it is relatively small considering the amount of potential the university has in the roster of authors and talents. Furthermore, the selection of academic journals for publishing within research universities might provide insights into the influence of the conducted research. In the specific setting, one can see that FF-UGM stands a considerable opportunity to raise the quality of its research activities and create a constituency within the worldly acknowledged and recognized academic journals. This will require a conscious effort in enhancing the standard of research which will culminate in a greater impact on publications. According to the burst analysis, it can be concluded that there are considerable possibilities to improve the research activities to increase the publication impact of FF-UGM. The quest to increase better research quality has a lot of potential in ensuring that FF-UGM would have more impact.

The implication of these findings has far reaching consequences in many fronts. To begin with, this research gives the researcher a comprehensive insight into the research patterns in the FF-UGM community, thus presenting workable advice to future research in this academic institution. In addition, the study extends to include viable implications of the study to most stakeholders. This assertion shows the importance of addressing the major issues and themes that emerge as pivotal factors towards attaining effective and sustainable forest management. Considering the findings expressed in this study, scholars and stakeholders could contribute immensely to the FF-UGM mission, not only with regard to enhancing knowledge, technology, and the management of tropical forest ecosystems.

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THE INITIAL IDENTIFICATION OF RAFFLESIA IN THE ANAMBAS ISLANDS, RIAU ISLANDS PROVINCE, AND THE CALL FOR PROTECTION

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THE INITIAL IDENTIFICATION OF RAFFLESIA IN THE ANAMBAS ISLANDS, RIAU ISLANDS PROVINCE, AND THE CALL FOR PROTECTION. *Rafflesia* sp., which was found in the Bukit Batu Tabir Production Forest area on Siantan Island, Anambas Islands Regency, Riau Island Province, became the starting point for further research. However, its existence in relatively unprotected Production Forests carries a risk of damage from human behavior because the presence of *Rafflesia* sp. has been known to the public since 2014. Based on the Direction Letter from the Riau Islands Provincial Environment and Forestry Office No. 13/070/1268.1/DLHK-04/2023 Medco E & P Natuna Ltd. together with the Center for Coastal and Marine Resources Studies IPB University, and the Production Forest Administration (KPHP) Unit VI of the Anambas Islands conducted an initial survey to identify species and surrounding habitats and build discussions with multi-stakeholders at the local level for the protection of *Rafflesia* sp. and their habitat. The research used morphological and observation methods, secondary data references, and discussions with related parties and Tarempa Selatan Village's government. The research indicated that the species in Bukit Batu Tabir, Siantan Island, is the *Rafflesia haseltii* species. This is a new finding of R. *haseltii* in the archipelagic landscape. Previous findings of R. *haseltii* were found on the mainland of Sumatra and Kalimantan Island. The interviews and discussions with the parties indicated that there are initiatives to protect *Rafflesia* sp. and its area in a collaborative scheme using the Social Forestry Village Forest mechanism. However, further studies are still required to determine the precise species based on microstructure studies and to strengthen the model of protection and management

Keywords: *Rafflesia* sp., *Rafflesia haseltii*, Anambas Islands, protection.

IDENTIFIKASI AWAL RAFFLESIA DI KEPULAUAN ANAMBAS, PROVINSI KEPULAUAN RIAU, DAN SERUAN UNTUK PERLINDUNGAN. Rafflesia sp. yang ditemukan di kawasan Hutan Produksi Bukit Batu Tabir di Pulau Siantan, Kabupaten Kepulauan Anambas, menjadi titik awal penelitian lebih lanjut. Namun, keberadaannya di Hutan Produksi yang relatif belum terlindungi memiliki risiko kerusakan akibat ulah manusia karena keberadaan Rafflesia sp. telah diketahui oleh masyarakat sejak tahun 2014. Berdasarkan Surat Arahan dari Dinas Lingkungan Hidup dan Kehutanan Provinsi Kepulauan Riau No. 13/070/1268.1/DLHK-04/2023 Medco E&P Natuna Ltd. bersama dengan Pusat Kajian Sumberdaya Pesisir dan Lautan IPB University dan Kesatuan Pengelolaan Hutan Produksi (KPHP) Unit VI Kepulauan Anambas melakukan survei awal untuk mengidentifikasi jenis dan habitat di sekitarnya serta membangun diskusi multipihak di tingkat daerah untuk perlindungan Rafflesia sp. dan habitatnya. Penelitian ini menggunakan metode morfologi dan observasi, referensi data sekunder, serta diskusi dengan pihak-pihak terkait dan pemerintah Desa Tarempa Selatan. Hasil penelitian menunjukkan bahwa spesies yang ditemukan di Bukit Batu Tabir, Pulau Siantan, adalah spesies Rafflesia haseltii. Ini merupakan temuan baru R. haseltii di lanskap kepulauan. Temuan R. haseltii sebelumnya ditemukan di daratan Sumatera dan Kalimantan. Hasil wawancara dan diskusi dengan para pihak mengindikasikan adanya inisiatif untuk melindungi Rafflesia sp. dan kawasannya dalam skema kolaboratif dengan

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menggunakan mekanisme Hutan Desa Perhutanan Sosial. Namun demikian, masih diperlukan kajian lebih lanjut untuk menentukan spesies yang tepat berdasarkan kajian struktur mikro dan memperkuat model perlindungan dan pengelolaannya.

Kata kunci: Rafflesia sp., Rafflesia haseltii, Kepulauan Anambas, perlindungan

I. INTRODUCTION

Rafflesia, a parasite that infects tropical vines in jungles across Brunei, Indonesia, Malaysia, the Philippines, and Thailand is threatened. By up to 42 species: 25 as 'Critically Endangered', 15 as 'Endangered', and two as 'Vulnerable,' and over two-thirds (67%) are not protected by regional or national conservation initiatives (Malabrigo et al., 2023). Nonetheless, Rafflesia faces challenges from habitat loss caused by deforestation, agriculture, mining, logging, and urbanization. Rafflesia relies on its host vines for existence; hence any disturbance to the vines also affects Rafflesia. Climate change may also influence the distribution and availability of pollinators and host vines, potentially reducing Rafflesia's reproductive success and genetic diversity. Another serious hazard to Rafflesia is human exploitation for medicinal or ornamental purposes, harvesting host vines for timber or fuel, and even tourism (Mozter, 2023; Malabrigo et al., 2023; Mahyuni et al., 2024). Kusuma et al. (2025) prompted conservation efforts to investigate its taxonomic integrity and naturalness

Until 2022, there were 13 species of Rafflesia found in Indonesia out of a total of 48 species that have received names in the world or accepted name status (WFO, 2023) in-situ and ex-situ. All species of the Rafflesiaceae family are declared as nationally protected plants according to Government Regulation No. 7 of 1999, and most species in this family are in Critically Endangered status (IUCN World Conservation Congress, 2020). Based on Indonesian national regulations in the Minister of Environment and Forestry Regulation No. P.160 of 2018 (second amendment to Ministry Regulation No. 20/2018) on protected species of animals and plants, 13 species declared protected are R. *arnoldii*, R. *bengkuluensis*, R. *gadutensis*, R. *haseltii*, R. *lawangensis*, R. *meijeri*, R. *micropylora*, R. *pricei*, R. *roschussenii*, R. *Tuan-Mudae*, R. *zollingeriana*, R. *patma*, and R. *kemumu*.

The number of Rafflesia species in Indonesia is the same as the *Rafflesia* sp. species found in Malaysia. *Rafflesia* sp. also grows in other Southeast Asian regions such as Brunei Darussalam, Thailand, and the Philippines (Barcelona et al., 2006). In general, the Rafflesiaceae family grows and develops in wet tropical forest landscapes, lowland and mountain forests, primary forests, or secondary forests adjacent to primary forests (Meijer, 1997). *Rafflesia* sp. becomes a parasite on *Tetrastigma* sp. with a growing period of 6 months to 4.5 years and a flower blooming period of only about 4-8 days but is expected to be able to grow throughout the year and even more (Hidayati & Walck, 2016; Mohd Elias et al., n.d.; Mursidawati et al., 2014; Susatya, 2011, 2020; Suwartini et al., 2008).

Rafflesiaceae is a holoparasite that cannot photosynthesize, so it relies on the host for growth, water supply, and nutrient intake (Renjana et al., 2022). As many as 11 species of *Tetrastigma* sp. are hosts for Raffleciaeae growth which also rely on large trees for climbing media. The relationship between Rafflesiaceae, hosts, and large trees still depends on the habitat. It is estimated that complex physiological conditions affect the vitality of Rafflesiaceae and its host, causing *Rafflesia* sp. to be susceptible to damage (Sulistiawati at el., 2022). Another pressure comes from anthropogenic factors either due to ignorance or irresponsible utilization (Mozter, 2023). Until now, Sumatra Island is a geographical area that has the most collection of *Rafflesia* sp. by ten species, which are spread along the Bukit Barisan Mountain Range from Aceh Province to Lampung Province (Susatya, 2011). Other locations are in the Bukit Tigapuluh National Park area in Jambi and Riau Provinces (Sofiyanti et al., 2007) and Gunung

Leuser National Park, Southeast Aceh (Asri, 2011).

From the search for national and international publications before this research, no scientific publications were found regarding the Rafflesia species in the Anambas Islands, Riau Islands Province. The latest new record on Rafflesia was published by Susatya et al. (2023) at Banyuwangi on R. z*ollingeriana*, which is already listed in the Ministerial Regulation 2018, locally known as "kembang banyu." Thus, our research also marks the first finding of *Rafflesia* sp. in the archipelagic landscape, while previously, this flora only existed in the main islands, particularly on three geographical landscapes: lowland forest, upland forest, and lowland (Kusuma et al., 2025). Based on information from the local government, local communities, and the Anambas Nature Enthusiast Community (KOMPAS), in 2014, a type of *Rafflesia* sp. was found in the Production Forest area in Batu Tabir, Tarempa Selatan Village, Siantan District. It was also conveyed that the knob of this flora was used as a herbal medicine.

According to KPHP VI Anambas, until 2023, nine locations of *Rafflesia* sp. have been recorded, with the main location being in Batu Tabir, which is a production forest area (Permanent and Limited Production Forest), but does not rule out the possibility that it is located outside the forest area. Local people identify it as *Rafflesia patma*, but from observations and physical comparisons as well as initial morphological characteristics, there are indications that the species that grows is a type of *Rafflesia haseltii*, such as those found in Bukit Tigapuluh, Riau-Jambi Province and West Kalimantan (Sari et al., 2019; Sofiyanti et al., 2007, 2008). As described by Susatya (2011), the species of R. *haseltii* is very easy to recognize and distinguish from its maroon perigone lobes, which have wide, dominant, and irregular rectangular white warts. In one lobe of perigone, the number of these warts ranges from 4-6 and can reach 70 cm in diameter when blooming. The R. *haseltii* complex is characterized by two types of ramenta: crateriform and toadstool. R. *haseltii* is a very rare and beautiful species (Susatya, 2011).

However, species conservation cannot be based just on one sector because Rafflesia habitat is broad and has other uses other than forestry. So, the conservation that is supported in Batu Tabir, combine conservation with collaborative management. In the context of resource management, collaborative management refers to the division of power and responsibility between the state and user groups in a resource management system (Pinkerton, 1989). According to Borrini-Feyerabend et al. (2000), collaborative management is a situation in which two or more players negotiate, define, and ensure the equitable sharing of management tasks, rights, and responsibilities over a specific area, region, or collection of natural resources. Ideally, co-management entails power sharing to make collaborative decisions. Thus, the paper seeks to convey the findings as initial material for further studies regarding the microstructure, morphology, and behaviour of *Rafflesia* sp. in Anambas. In addition, this study also aims to identify a model of management and protection based on collaboration between business entities, the government, and local village communities so that the existence of *Rafflesia* sp. and its habitat can be properly managed and protected before obtaining a firmer protection status.

II. MATERIAL AND METHOD

A. Study Location

The study location that has been mapped was an area of 49.95 hectares in the Bukit Batu Tabir area, Tarempa Selatan Village, Siantan District, Anambas Islands Regency, Riau Island Province. This area includes the core distribution zone of *Rafflesia* sp., the points of which have been plotted, as well as the buffer and utilization zones if they are to be managed as one of the protected ecotourism locations. Officially, Bukit Batu Tabir is included in the Production Forest area, which is under the management of the Riau Islands Provincial Forestry Office,

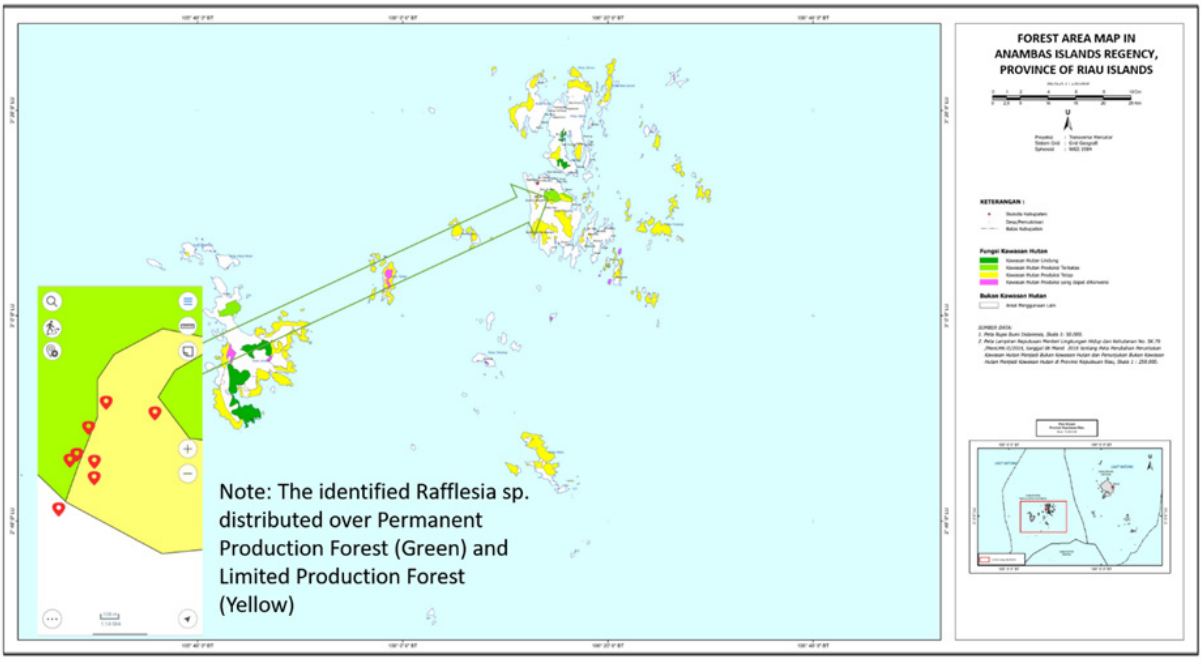


Figure 1. Map of Identified *Rafflesia* sp. in Anambas Islands (Source: KPHP VI 2023)

where at the site level, it is the responsibility of the Production Forest Administration Unit (KPHP) VI of the Anambas Islands.

B. Methods

Data regarding Rafflesia species at the Siantan Island location were collected from secondary data from previous expert studies, as well as observations and morphological identification of *Rafflesia* sp. flowers at the location. The results of this morphological identification will be compared with the physical characteristics found by previous experts. Rafflesia's taxonomy is still based on the shape and morphological structure of the flower. The distinguishing character of the Rafflesia species used in this study is based on the classification of (Meijer, 1997), which has been modified by (Nais, 2001):

a) The size of the diameter of the flower when it blooms.
b) Diaphragm aperture (hole in the middle of the flower)
c) Number of processes (sticks out like thorns in the middle of the flower)
d) Number and size of warts covering the perigone lobe and the diaphragm (from the opening of the hole to the edge of the diaphragm).
e) Number of anthers
f) The length and structure of the ramenta (the hair-like structures that grow on the walls of the diaphragm) and their location.
g) Number of annuli at the base of the perigone (petals).

However, for this study, only morphological observations were made on the outer side of the flower, so only four parameters were used: the diameter of the flower when blooming, the diameter of the diaphragm aperture (the hole in the center of the flower), the number of processes (a thorn-like protrusion in the middle of the flower), and the number and size of warts that are scattered covering the perigone lobes. The other three characters were left for further research.

Meanwhile, social and institutional information and data were collected through interviews with 22 parties who had interacted with *Rafflesia* sp. in Batu Tabir, such as the Anambas Islands Production Forest Administration (KPHP VI), the Anambas Nature Enthusiast Community (KOMPAS), and the Village Government and forest conservation community groups of Tarempa

Selatan Village, where the *Rafflesia* sp. is located. Other supporting data are the results of the initial mapping conducted independently by the related parties above and the supporting secondary data. All the collected data and information were analysed descriptively.

III. RESULT AND DISCUSSION

A. Result

The existence of *Rafflesia* sp., which grows in village locations and forest areas, encourages the initiation of communication and collaboration between the Provincial Forestry Service and the Village Government. Medco E&P Natuna Ltd., with its technical partner CCMRS IPB, is a third party that voluntarily develops a model for managing the area while protecting the habitat of *Rafflesia* sp. in the Anambas Islands. This tripartite collaboration is an effort to be initiated to protect the endangered species of *Rafflesia* sp. while at the same time providing opportunities for the benefit of the local community and opportunities for conservation education for the public around the habitat area of *Rafflesia* sp.

The initial exploratory study of the Rafflesia flower found 37 Rafflesia individuals, consisting of three blooms and 34 knobs (Rafflesia flower candidates). The Rafflesia flower blooms, and the knobs are scattered at four points. At the first location, there were two individuals, which is an individual flower that had bloomed and a large knob with a diameter of about 7 cm in an area of 31 m^2. In the second location, there is one large Rafflesia knob in an area of 37.95 m^2, while in the third location, there are two large and one small Rafflesia knob in an area of 97 m^2. The highest population of Rafflesia blooms was found in the fourth location, where as many as two Rafflesia flowers were blooming, one rotted Rafflesia flower, and 12 knobs (Rafflesia in this area is spread over an area of 459.46 m^2 in moderate slopes site. Further observations also found that the host of Rafflesia was assessed to be a *Baccaurea* sp. species that grows around the site.

The fifth location is the habitat of Rafflesia, which is most frequently visited by the community during their visit to Bukit Batu Tabir. Around the *Rafflesia* sp. growing area has been fenced with bamboo to protect the population from being damaged and stepped on. Rafflesia's knobs are usually hidden behind the litter on the forest floor, so the knobs may be stepped on and died. A total of 17 Rafflesia flower knobs were found, but during field observations, no flowers were found blooming in this area. The detailed distribution points can be seen in Figure 3.

a. *Rafflesia* sp. when blooming at Location One

b. Rafflesia's Knob at Second Location

c. Rafflesia's Knob at Third Location

d. Rotted Rafflesia at Fourth Location

e. Rafflesia's Knob at Fourth Location

f. Rafflesia's Knob at Fifth Location

Figure 2. The condition of the *Rafflesia* sp flower at the observation location

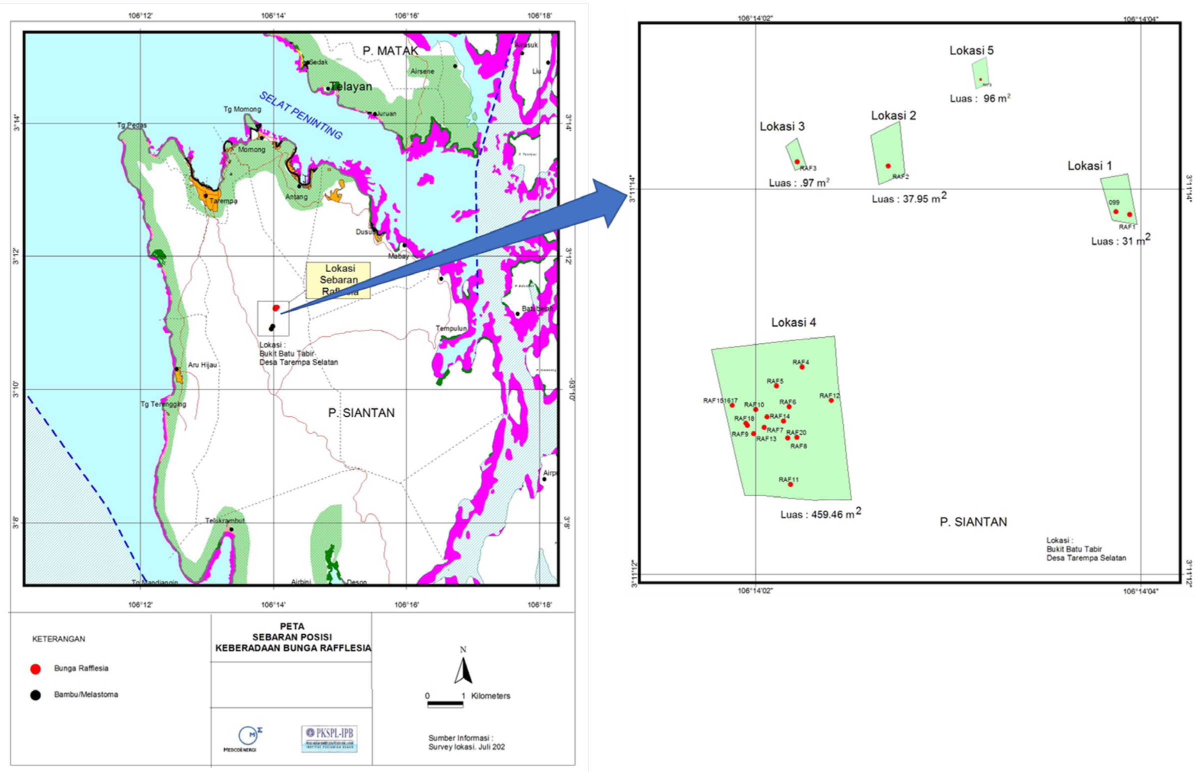


Figure 3. The distribution points of *Rafflesia* sp. in the study location (processed data)

Table 1. Morphology of *Rafflesia hasseltii* in Siantan Island

Flower number	Perigone lobes	Mature flower diameter (cm)	Number of warts in the Perigone lobe	Diaphragm diameter (cm)	Diaphragm form	Diaphragm aperture (cm)	Diaphragm nodule	Processes number
R 1	5	25.68 and 30.16	10-19	14.97 and 13.44	Hexagonal rounded	5.86 and 5.33	60	13
R 2	5	29.48 and 38	26-33	17.24 and 17.29	Hexagonal rounded	7.44 and 6.18	40	17
R 3	5	28.85 and 36.18	17-21	18.33 and 18.13	Hexagonal rounded	6.6 and 7.7	56	15

Table 2. Comparison of R.*hasseltiii* morphology on Siantan Island to previous studies

Morphology character	*R. hasseltii* in Siantan Island*	*R. haseltii* (Puad et al., 2020)	*R. haseltii* (Sari et al., 2019)	*R. haseltii* (Sofianti et al., 2007)	*R. hasseltii* (Zuhud et al., 1999)	*R. hasseltii* (Meijer et al., 1997)
Flower Size	26-38 cm	47-53 cm	35 cm	33–35 cm	28.5 cm	38-50 cm
Number of perigone lobes	5 lobes	5 lobes	5-6 lobes	5 lobes	N/A	5 lobes
Size of perigone lobes	11-18 cm x 7-13 cm	13.5–16 cm long x 17.5–22 cm wide, apex rounded, margin entire. Reddish-orange with whitish-pinkish warts	11.3–14 × 7–11 cm	10–12×11–14 cm, bright red brick	N/A	11.5–13 × 15–17 cm
Blotches pattern on perigone lobes	The blotches are randomly scattered across the surface of the perigones. Their color varies, ranging from light orange to pinkish.	coalesced, large, ranging from 1.2–16 cm long x 0.7–9.2 cm wide	Each perigone displays 10 blotches, distributed sporadically on the perigone's surface. The color of these blotches ranges from light orange to pinkish.	Coverage ranges from 46.23% to 60.15%, and the density varies between 2 to 12, appearing whitish in color.	N/A	5 prominent pustules are arranged horizontally. The size of each pustule 5 × 3 to 10 × 1 cm
Diameter of diaphragm	13-18 cm, round or irregular shape, light orange to reddish, and ultimately darker when dying	20–27 cm whitish with a brownish zone near the diaphragm rim, diaphragm rim entire	12-12.5 cm, round or slightly hexagonal, light orange in color.	4-7 cm, mostly pentagonal	4.2 cm	N/A. The diaphragm has a light whitish or yellowish color with a dark brown area near its rim. Additionally, it features a ring of rounded or elongated dark brown warts at its base
Shape and diameter of diaphragm aperture	5-8 cm, circular and angular	6.5–12.1 cm; diaphragm aperture suboval, ratio diaphragm/aperture 1.7:1.0	4.8 cm		N/A	N/A

Morphology character	*R. hasseltii* in Siantan Island*	*R. haseltii* (Puad et al., 2020)	*R. haseltii* (Sari et al., 2019)	*R. haseltii* (Sofianti et al., 2007)	*R. hasseltii* (Zuhud et al., 1999)	*R. hasseltii* (Meijer et al., 1997)
Number of warts at diaphragm	40-60 warts	42–59, round to oval, white with red/orange circular at the base	N/A rounded or elongated, reddish brown to light brown	21-30 rounded and sometimes elongated, bright red, and distinctly visible	N/A	N/A
Number of processes	10-22	23–24, orange color at the base, gradually becoming darker brown towards the apex, 1.8–2.3 cm long x 0.3–0.5 cm wide	15-21, height ranges from 1.5 to 1.8 centimeters, and the tips are spathulate with a wavy edge, featuring bristles along the margin.	13–17, with height around 1.5–1.7 cm, not flattened, styliform	15	15–24 cm, 15–24, colored resembling the disk, appearing light yellowish overall, but it becomes dark brown at the apex. Unlike some other species, it is not flattened in shape.

*Study of Rafflesia in Siantan Island 2023

R1 R2 R3

Figure 4. *Rafflesia hasseltii* found in the study on Siantan Island

The morphological characteristics of the three flowers are examined in the following discussion. A detailed set of individual observations is presented in Table 1, and the comparison of R. *hasseltiii* morphology on the Siantan Island to previous studies is provided in Table 2.

Perigone lobes

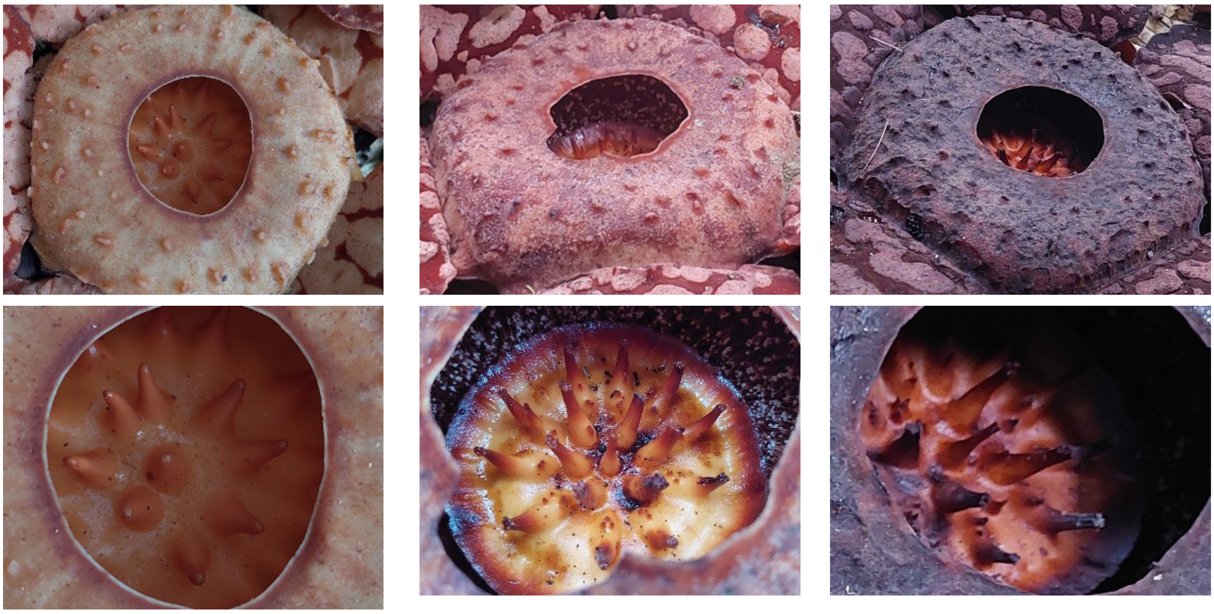
The number of perigone lobes in the three Rafflesia individuals was five. The upper surface of the perigone lobes was soft, reddish-orange in color, and covered in large, coalescent patches. The lobes were slightly rough in texture, white, light orange, to pale pink in color. Warts that were scattered on the lobes have the shape of separate, wide dots, and some spots were elongated. The shape of the perigone lobes in flowers can be seen in Figure 4.

Diaphragm

The shape of the diaphragm of *Rafflesia hasseltii* on Siantan Island resembles a pentagon with nodules on the surface. The vertical and horizontal diaphragm diameters for individual 1 (R1) were 14.97 cm and 13.44 cm, individual 2 (R2) were 17.24 cm and 17.29 cm, and individual 3 (R3) were 18.33 cm and 18.13 cm, respectively. The upper surface of the diaphragm has a soft texture, with a thick skin, and is rather hard (Figure 5).

Diaphragm aperture

The diaphragm apertures found in *Rafflesia* sp. are circular (Figure 5: R1 and R3) or irregular



R1 R2 R3

Figure 5. Diaphragm, diaphragm aperture, and diaphragm nodule

(circles have corners (see Figure 5: R2). There was a white circular line around the hole and a thin, finely textured margin, with the color of the hole line being blackish orange (darker) than the color of the other top surface of the diaphragm.

Diaphragm nodules

Diaphragm nodules are structures in the form of small dots with an embossed and hard texture, scattered circularly on the surface of the diaphragm. Irregular-shaped nodules, orange to reddish in color and black in color on Rafflesia, have started to wither and die (Figure 5).

Processes

The process is a conical structure on the disc surface. The surface is very smooth and sleek. Generally, the process is in the form of a single cone, but sometimes, cones that are attached are also found. The number of processes varies. Based on the counting of the three bloomed Rafflesia and the condition of the procession which is still quite intact, indicating that the number of processes of the three bloomed Rafflesia ranges from 13-17 stems. The stem is cylindrical with a wider base than the apex. The ends of the process are very sleek and blunt and break easily). The color ranges from pale creamy yellow to reddish-orange and darker. The process attaches to a surface called a disc, which is located in the center of the flower. The surface of the Rafflesia flower disk can be flat (Figure 5: R1 and R3), convex at the bottom where the process attaches (Figure 5: R2), and concave (no concave disc shape was found on *Rafflesia hasseltii* at the study site).

Rafflesia hasseltii Suringar was initially documented in 1879, having been collected from Sumatra (Latiff & Mat-Salleh, 2001). Subsequently, it has been discovered in various other areas in Indonesia, spanning three provinces in Sumatra: West Sumatra, Riau, and Jambi (Meijer, 1997; Zuhud et al., 1998), as well as in two locations in Sarawak, in Samunsam, Malaysia (Nais, 2001) and Tanjung Datu (Ong, 2004), the most recent sighting of *Rafflesia hasseltii* in Sambas, West Kalimantan, which marks the first-ever record of this species in Kalimantan.

The team identified the characteristics of Rafflesia from the parameters of the number of perigone warts, flower diameter, number and pattern of warts, the diameter of the diaphragm, the diameter of the diaphragm aperture, the number of nodules on the diaphragm, and the number of processes. The rafflesia study conducted on Siantan Island showed that there was an alleged similarity of the species with *Rafflesia haseltii* from the morphological characteristics of the flower. The *Rafflesia hasseltii* found in the study had flower width, number of perigone lobes, size of perigone lobes, and wart patterns on perigone lobes that were almost the same as previous expert findings.

However, in terms of the diaphragm diameter, R. *hasseltii* on Siantan Island has a larger diaphragm diameter compared to R. *hasseltii* in Jambi and Riau (Sofiyanti et al., 2007; Zuhud et al., 1998), but smaller than R. *hasseltii* which discovered in Sarawak by Puad et al. (2020). The shape and size of the diaphragm aperture diameter in populations on Siantan Island are also almost the same as in populations on Kalimantan Island (Sari et al., 2019) and Sarawak (Puad et al., 2020). Warts in the Siantan Island population are very similar to those in Sarawak, with 40-60 warts per individual of R. *hasseltiii*. The number of processes in the population on Siantan Island also has similarities with the populations in the other four study locations in Sarawak, Kalimantan, Jambi, and Riau, with a range of the number of processes of at least 13 stems and a maximum of 24 processional stems. In contrast, the number of processes on Siantan Island ranges from 10 -22, which in this case is still within that number range. Meanwhile, if seen from the appearance of the R. *hasseltii* image, the population on Siantan Island is similar to the population in Tanjung Datu, Sarawak (Ong, 2004; Sofiyanti et al., 2007).

Based on the morphological characteristics of the three Rafflesia that have bloomed, this initial study concluded that the species on Siantan Island, the Anambas Islands, is the *Rafflesia hasseltii*. Although at first glance it has a resemblance to R. *cantleyi*, a study of *Rafflesia cantleyi* conducted by Solms-Laubach (1910) shows that the white wart pattern on R. *cantleyi* only has a small and separate pattern, while R. *hasseltii* has a larger and merged pattern. The study of Sofiyanti et al. (2007) stated that the morphological characters of *Rafflesia hasseltii* are indeed diverse, especially the variations in warts on the perigone which sometimes make identification difficult. However, the main distinguishing character is the warts that dominate the perigone lobes up to 60.15%, which is only found in R. *hasseltii*. However, as an interim report, the author still considers that further studies are needed involving experts to ensure that this type of Rafflesia can gain international recognition in time.

Ecosystem conditions

Climate data from Tarempa Meteorological Station for 2010-2021 shows an annual average rainfall of 3,872.53 mm/year. The average ratio of dry months to wet months is 0.2529 or 25.29%. Thus, according to the Schmidt and Ferguson climate classification, the climate type around the Anambas includes climate type B with relatively few dry months compared to the number of wet months. The highest monthly average rainfall is found in December at 401 mm/month; months with high rainfall are found in July, November and December. Low rainfall is found in February-April.

Based on its physical soil, the forest ecosystem around the habitat for the rare flower *Rafflesia* sp. is a red-yellow podzolic soil with its bedrock containing granite, alluvial soil, organosol soil, and gley humus. Changes in wind direction strongly influenced the climate at the study site. The dry season usually occurs from March to July.

The survey showed that there were three main families in the study area: Myrtaceae, Euphorbiaceae, and Dipterocarpaceae. The Dipterocarpaceae family seems to dominate the ecosystem type in this area. The species found during the survey were *Syzygium aemum*, *Shorea gibbose*, *Lithocarpus reflexus*, *Shorea acuminata*, and others. Bukit Batu Tabir Forest in Tarempa Selatan Village, in general, is a hilly secondary forest with production forest status. The *Rafflesia hasseltii* species grows on *Tetrastigma* spp. The tree vegetation found in this forest is Dipterocarpaceae, Dilleniaceae, Fabaceae, and Lauraceae families. In this forest, there were

a. Protective fence for *Rafflesia hasseltii* at fifth location

b. Spesies Baccaurea sp. near first location

Figure 6. Vegetation conditions around the *Rafflesia* sp. on Bukit Batu Tabir Forest

also *Baccaurea* sp., *Campnosperma auriculatum*, *Canarium littorale*, *Macaranga* spp., *Syzygium lineatum* and *Shorea acuminata*.

The highest tree density in the study area was relatively below the standard range for the number of tree species in wet tropical forests. However, because no vegetation analysis has been carried out in all areas, the available data was inadequate and did not represent tree density conditions in the study area. The distribution and presence of vegetation types in the forest at the study site were still low. The low tree species richness in the study area is likely due to limited habitat, which only allows for the survival of certain species. Forest structure and tree species composition in the study area may also be influenced by several other factors, such as the location and position, as well as the shape and size of the forest ecosystem.

B. Discussion

a. Five important issues in the conservation of *Rafflesia* sp. and the habitat

According to the Indonesian Conservation Strategy and Action Plan of *Rafflesia arnoldii* document 2015-2025, the Rafflesia has a very high risk of extinction in nature if it is not anticipated soon. Naturally, the reproduction of *Rafflesia* sp. is relatively slow, with a high mortality rate, and is highly dependent on specific conditions involving the host and other tall trees. Other threats come from habitat destruction, natural predation, fungi, and climates that are too wet. Anthropogenic factors, damage caused by unmanaged tourist visits, misuse of herbal medicine, hunting, and land conversion are the causes of damage to Rafflesia and its habitat. In Indonesia, *Rafflesia* sp. occupies a space of less than 500 km^2 with populations or subpopulations whose numbers fluctuate extremely (Susmianto et al., 2015).

So far, the conservation of *Rafflesia* sp. has been carried out in two ways: in-situ conservation and ex-situ conservation (Latiff, 2018), and continues to be promoted so that it runs in an integrated manner throughout the world (IUCN World Conservation Congress, 2020). In-situ conservation is a form of protection and prevention of species damage in the original location where the species grows and interacts with dynamic local systems, while ex-situ conservation focuses on efforts to preserve their genetic material (Dulloo et al., 2010; Mursidawati, 2017). Seeing the limitations in the Rafflesiaceae conservation efforts, the existence of initiatives from the community on Rafflesiaceae species that are outside the forest area needs to get support from the policy. One of the voluntary in-situ conservation that has been carried out is the designation of a 2000-hectare area for R. *arnoldii* conservation in the Educational Forest belonging to the Muhammadiyah University of Bengkulu with legitimacy from the Indonesian Minister of Environment and Forestry (Purwanto, 2017).

This paper specifically only discusses in-situ protection schemes in the form of area or habitat management as a conserved area. The conservation approach implemented in the *Rafflesia* sp. in Batu Tabir emphasizes efforts to reduce pressure on species due to natural and anthropogenic factors as well as maintaining ecological processes and life support systems, maintaining genetic diversity, and ensuring the sustainable use of species and ecosystems in a biosphere. The scope of this effort follows the national Rafflesia Conservation Action Plan/SRAK 2015 (enacted by Minister of Environment and Forestry No. P71 Year 2015), which will focus on conservation management programs through development research, preparation of management rules and policies, partnerships and cooperation, communication and public awareness; and fundraising (Susmianto et al., 2015). From the conservation aspect, the SRAK 2015 is a good response from the government to plan for the protection of Rafflesia, although it is not enough.

According to Widyatmoko (2019), the existence of Indonesia's rare plants faces five threats: habitat loss, over-use, invasive species, pollution, climate change, and biological factors. On the experience in Kelantan, Fauzan et al. (2021) stated that there are several challenges as well as opportunities in protecting Rafflesia: large-scale agricultural development, formulation of a management plan, scientific research on *Rafflesia* sp., ecotourism, involvement of local community and funding. Almost the same challenges are also experienced by Indonesia. From the results of observations at the site, efforts to protect *Rafflesia* sp. in Batu Tabir place five important issues as the future conservation research agenda: the need for collaboration between government-community-private in managing and utilizing *Rafflesia* sp.; the need for physiological and morphological scientific studies to ascertain the species in the Anambas Islands; the need for an integral management plan based on scientific data; stipulation of delineation for area protection; and responsible use to meet conservation, economic and social welfare needs.

There are at least two main challenges to protecting Rafflesiaceae in Indonesia today. First, there is no accurate data regarding the location, type, and distribution of Rafflesiaceae in conservation areas or outside conservation forest areas. This condition has implications for the possibility that Rafflesiaceae will disappear before being identified because it is located outside a conservation area that is not protected and managed. The need for scientific studies regarding the physiology, morphology, and behavior of Rafflesiaceae species and the protection of forest areas are two things that cannot be separated. The second challenge is the absence of derivative policies that are integral and applicable as well as cross-sectoral with adequate funding to carry out the Rafflesia Conservation Strategy and Action Plan that has been prepared.

We can take a precedent for mangrove management that has legitimacy with Presidential Decree No. 73 of 2015 on the Implementation of Coordination of Coastal Areas and Small Islands in one window at the Ministry of Marine and Fisheries, which is the legal basis for the Ministry of Marine and Fisheries (MoMaF) and Ministry of Environment and Forestry (MoEF) to allocate their respective resources to protect mangrove ecosystems on the coast. It is appropriate that a species as important as Rafflesia and its habitat can obtain strong legality so that cross-agency and multistakeholder work have a legal basis. Designation of protected areas in areas and with collaborative management applications such as Social Forestry can be an opportunity to turn sites of high conservation value into conservation sites. The site itself is part of The Indicative Map of Social Forestry (PIAPS) have been designated by the government.

b. Utilization of the area within the framework of collaborative management at the site level

Departing from national directives for Rafflesia conservation and learning from other countries, Medco E&P Natuna Ltd., together with the Center for Coastal and Marine Resources Studies of IPB University, trying to develop a development scheme for the utilization of the *Rafflesia* sp. protected area collaboratively. This effort is a voluntary multistakeholder initiative with the main actors being the Riau Islands Provincial Forestry Office as the manager of the production forest area, the village government of Tarempa Selatan, and Medco E&P Natuna Ltd. as a corporation operating in the Anambas Islands Regency by providing its resources to implement habitat conservation and Rafflesia species sustainably. Based on the results of the initial study, what has become the focus of national conservation efforts is also found in the Batu Tabir location in the Anambas Islands.

From the interviews conducted during the field study of the village government, representatives of nature activists groups, and KPHP VI, there was a commitment that all parties wanted to protect the *Rafflesia* sp. flower as well as other types of endemic vegetation in the Bukit Batu Tabir area and the ecosystems in it. From the regional spatial planning aspect, the Bukit Batu Tabir area is declared a water catchment area, so it has the status of an essential area that is vulnerable if it is not managed properly (see Regional Regulation of Anambas Regency Number 03 of 2013 on Anambas Islands Regency Spatial Plan 2011-2031, Article 37 (b)). Seeing the suitability of the space, the structure of the person in charge, and the existing effective management, there is a common vision that the scheme to be used is the Village Forest Scheme, which will be utilized as an Ecotourism location. This means that sustainable use can be conducted on a village basis (village government as the responsible holder) without reducing the carrying capacity of the environment for the benefit of environmental education and conservation.

The Village Forest Scheme is included in the Social Forestry management system under the Directorate of Social Forestry Area Preparation, Directorate General of Social Forestry and Environmental Partnerships (PSKL), which aims to enable communities to access benefits from the forest. By definition, a Village Forest (HD) is a forest area in a protected forest area or production forest that has not been burdened with permits. These forests are allocated to village institutions to be managed or utilized according to their function for the realization of a prosperous community and sustainable forest. HD management approval will be given at the request of the village for a period of 35 years and can be extended. It is written in the Regulation of the Minister of Environment

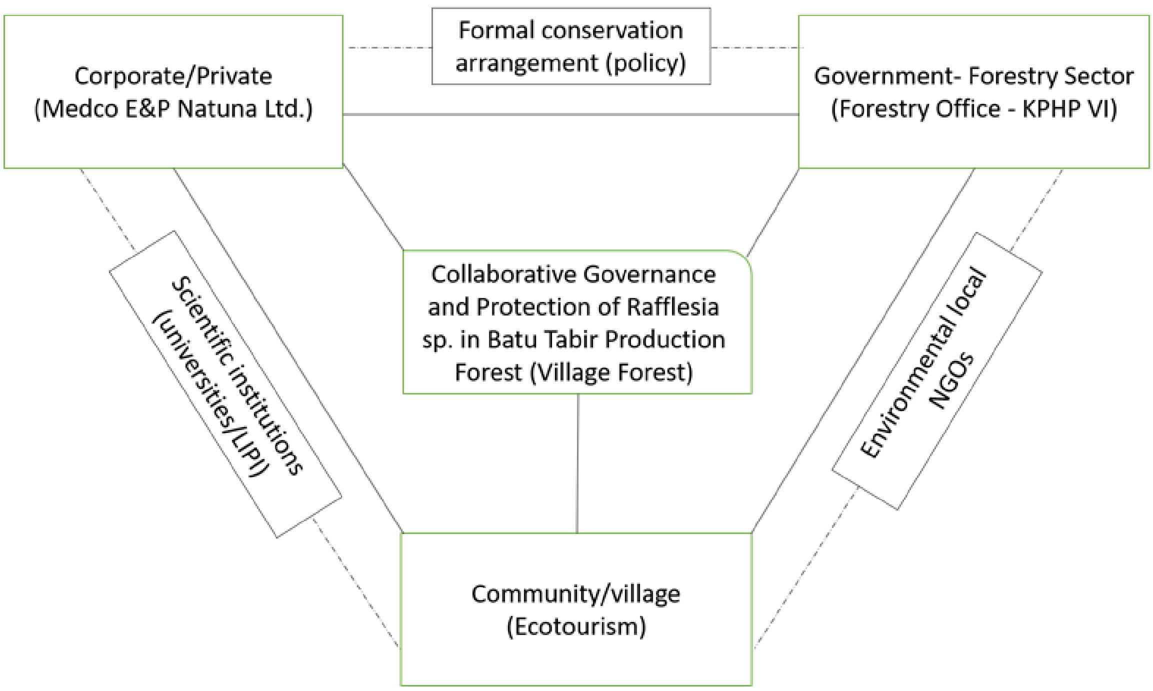


Figure 7. Scheme of the Collaborative Rafflesia Management Plan in the Anambas Islands.

and Forestry No. 9 of 2021 on Social Forestry Management (Direktorat Jenderal, 2021).

c. Future agenda

Departing from the types of challenges and opportunities for Rafflesiaceae conservation above, several follow-ups are still needed by various groups, both government, academics, the public, and business entities, to cover the deficiencies in the conservation of this rare flower. The future agenda consists of three parts: the research agenda, the partnership agenda, and the policy agenda. On the research agenda, science-based institutions and universities are expected to continue studies to determine the types, behavior, and sensitivity levels of Rafflesiaceae in Indonesia. The agenda for the partnership is to increase the number of applications to pool resources and share responsibility for the protection of Rafflesiaceae. Every Rafflesiaceae finding should receive major attention to be followed up immediately with the consolidation of many parties to determine the form of protection for Rafflesiaceae and its habitat as soon as possible. Meanwhile, the policy agenda is to formulate guidelines and legitimacy for many parties to implement conservation in various official management schemes. Applied regulations after the SRAK 2015 can be provided so that each party has guidelines for taking the stages of protection and management without having to conflict with certain laws and authorities.

Since the finding of *Rafflesia* sp. in the Anambas Islands from 2014 to 2025, there has not been a single form of scientific report or publication from an academic institution that explains the morphology, physiology, behavior, and level of sensitivity of *Rafflesia* sp. in the Anambas Islands. Likewise, no partnership steps have been initiated at the site level. Institutions such as the Forestry Office, NGOs, the community, the village government, and the Natural Resources Conservation Agency (BKSDA) have not been on the same platform. It is suggested they can be more organized in the long term to protect Rafflesiaceae and its habitat in Bukit Batu Tabir. In general, conservation may be carried out in a Conservation Area or Protected Area scheme so that its effectiveness can be measured (Mat Salleh et al., 2006). However, until now, there has been no official and accurate record of how much Rafflesia habitat is in conservation areas or outside conservation areas.

Of the various policies regarding conservation, the policy that has opportunities to manage and protect Rafflesiaceae is the Village Forest scheme because the location of Rafflesiaceae is in a Production Forest Area. However, the resources owned by the community and village government are not sufficient to develop a utilization framework in the form of Village Forest or Social Forestry. Social Forestry in the form of Village Forests is the first step to protect and conserve Rafflesiaceae more comprehensively through a series of environmental education and conservation management. The collaborative scheme offered by Medco Natuna E&P Ltd. is a voluntary effort from the business entity to support communities in managing their natural resources while protecting endangered species and their habitats. There are four emphases in the collaboration scheme: Further scientific study of the species found in Bukit Batu Tabir; Assistance in the process of submitting and establishing Village Forests; Preparation of the *Rafflesia* sp. ecotourism master plan; and Operationalization of eco-education-based conservation of *Rafflesia* sp. so that Rafflesia can become a special tourist destination that is integrated into the Anambas Islands Regency tourism agenda.

IV. CONCLUSION

From the initial observations results based on the physical characteristics of the flower, *Rafflesia* sp. in Tarempa Selatan Village, Siantan District, Anambas Islands Regency is a species of *Rafflesia haseltii* as found previously in Kalimantan and Riau on Sumatra Island. Rafflesia in the Bukit Batu Tabir Production

Forest Area is the first finding of Rafflesiaceae in Anambas Islands Regency, which lives in a wet secondary forest ecosystem with moderate shade levels. The host for *Rafflesia haseltii* is *Tetrastigma* sp. vines on the Bacauceae tree. Approximately 50 hectares of the area is a production forest area that has minimal disturbance from agricultural activities and has the opportunity to be managed collaboratively between the village government, the Riau Islands Provincial Environment and Forestry Office, and corporate parties.

The findings of this initial investigation have various implications: a) Contribute to the documentation of Rafflesiaceae in Indonesia and around the world; b) Invite parties to complete the study of species and habitat characteristics in the vicinity; c) Invite local governments and policymakers in the fields of forestry and natural resource conservation to develop protection mechanisms; and d) Educate and involve local communities in protecting Rafflesia species and forest habitat areas. The recommendation we can offer to policymakers and other parties is continuing the study of *Rafflesia* sp. under multiparties and experts. The second recommendation is preparing requirements for managing the Rafflesia protected area in the Village Forest scheme.

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We realize that the findings and analysis in this paper are not final yet, so this publication is an attempt to invite many parties to protect and manage *Rafflesia haseltii* in Batu Tabir. With all humility, we would like to thank the Environment and Forestry Office of the Riau Islands Province for granting permission to survey the Batu Tabir Production Forest. We are also grateful to the Production Forest Administration (KPHP) Unit VI of the Anambas Islands, who accompanied the team during the field survey. Also to Medco E&P Natuna Limited for facilitating us to conduct a field study. We also thank the ranks of the Tarempa Selatan Village Government, as well as all institutions and individuals in the Anambas Islands, who have provided the team with valuable information during the information gathering.

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ASSESSING BIODIVERSITY AND TOURISM POTENTIAL IN SAMPUNONG BOLO WILDLIFE SANCTUARY, PHILIPPINES: STRATEGIES FOR REHABILITATION AND SUSTAINABLE DEVELOPMENT

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ASSESSING BIODIVERSITY AND TOURISM POTENTIAL IN SAMPUNONG BOLO WILDLIFE SANCTUARY, PHILIPPINES: STRATEGIES FOR REHABILITATION AND SUSTAINABLE DEVELOPMENT. This mixed methods research study investigates the biodiversity and tourism potential of Sampunong Bolo Wildlife Sanctuary in the Municipality of Sara, Province of Iloilo, Philippines, aiming to identify floral and faunal species, assess their tourism appeal, and propose strategies for rehabilitation and sustainable development. Primary data were collected through interviews and focus-group discussions with 14 purposively selected barangay residents and officials, complemented by secondary data from the Department of Environment and Natural Resources-Community Environment and Natural Resources Office (DENR-CENRO) of Sara. Thematic analysis was employed to analyze the interview data, identifying patterns and themes relevant to the sanctuary's current state and its potential for revival. The DENR-CENRO data revealed 39 faunal and 100 floral species, highlighting the sanctuary's rich biodiversity. Moreover, the findings suggest significant tourism potential, with opportunities for wildlife observation, recreational activities, and cultural and economic activities. To rehabilitate the sanctuary, recommendations include implementing protective policies, enhancing infrastructure, installing informative signage, and employing environmental conservation efforts. These measures are expected to preserve biodiversity, improve visitor infrastructure, and promote sustainable tourism practices. Future research should focus on long-term ecological monitoring and assessing the socio-economic impacts of tourism development on local communities.

Keywords: Sampunong Bolo Wildlife Sanctuary, biodiversity, tourism potential, sanctuary rehabilitation, sustainable development, Philippines

MENILAI KEANEKARAGAMAN HAYATI DAN POTENSI WISATA DI SUAKA MARGASATWA SAMPUNONG BOLO, FILIPINA: STRATEGI UNTUK REHABILITASI DAN PEMBANGUNAN BERKELANJUTAN. Studi penelitian dengan metode campuran ini menyelidiki keanekaragaman hayati dan potensi wisata Suaka Margasatwa Sampunong Bolo di Kotamadya Sara, Provinsi Iloilo, Filipina, yang bertujuan untuk mengidentifikasi spesies flora dan fauna, menilai daya tarik wisatanya, dan mengusulkan strategi untuk rehabilitasi dan pembangunan berkelanjutan. Data primer dikumpulkan melalui wawancara dan diskusi kelompok terfokus dengan 14 penduduk dan pejabat barangay yang dipilih secara purposif, dilengkapi dengan data sekunder dari Departemen Lingkungan Hidup dan Sumber Daya Alam-Kantor Lingkungan Hidup dan Sumber Daya Alam (DENR-CENRO) Sara. Analisis tematik digunakan untuk menganalisis data wawancara, mengidentifikasi pola dan tema yang relevan dengan kondisi cagar alam saat ini dan potensinya untuk dihidupkan kembali. Data DENR-CENRO mengungkapkan 39 spesies fauna dan 100 spesies bunga, menyoroti keanekaragaman hayati cagar alam yang kaya. Selain itu, temuan tersebut menunjukkan potensi pariwisata yang signifikan, dengan peluang untuk pengamatan satwa liar, kegiatan rekreasi, dan kegiatan budaya dan ekonomi. Untuk merehabilitasi suaka margasatwa tersebut, rekomendasi yang diberikan meliputi penerapan kebijakan perlindungan, peningkatan infrastruktur, pemasangan papan nama yang informatif, dan upaya pelestarian lingkungan. Langkah-langkah ini diharapkan dapat melestarikan keanekaragaman hayati, meningkatkan infrastruktur pengunjung, dan mempromosikan praktik pariwisata yang berkelanjutan. Penelitian di masa depan harus berfokus pada pemantauan ekologi jangka panjang dan menilai dampak sosial-ekonomi.

Kata kunci: Suaka Margasatwa Sampunong Bolo, keanekaragaman hayati, potensi pariwisata, rehabilitasi suaka margasatwa, pembangunan berkelanjutan, Filipina

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I. INTRODUCTION

Wildlife sanctuaries have emerged as crucial destinations for ecotourism, integrating environmental conservation, community empowerment, and sustainable development. Globally, these protected areas are gaining attention not only for their biodiversity but also for their potential to attract eco-conscious travelers and provide economic opportunities for surrounding communities (Acquah et al., 2022). For example, studies in Bangladesh and India have highlighted how sanctuaries such as the Rema-Kalenga and Biligiri Rangaswamy Temple Wildlife Sanctuary serve not only as ecological havens but also as models of tourism-driven conservation and cultural engagement (Rana et al., 2010; Balasubramanian, 2022). The evolving role of social media has further amplified the visibility of such destinations, with user-generated content influencing travel choices and public attitudes toward wildlife protection (Kredens & Vogt, 2023).

However, alongside this positive trajectory, sanctuaries worldwide are also confronting several critical challenges. These include the misuse of conservation labels for commercial gain (Winders, 2017), increased human-wildlife conflicts (Kala & Kothari, 2013), encroachment on natural habitats (Galodha et al., 2022), and insufficient governance to regulate activities that threaten biodiversity (Fultz, 2017; Hussain, 2016). These issues reflect the urgent need for locally grounded yet comprehensive strategies that reconcile environmental protection with tourism development and community interests.

In the Philippine context, the potential of wildlife sanctuaries to contribute to sustainable tourism remains underutilized in many areas. One such case is the Sampunong Bolo Wildlife Sanctuary, located in Barangay Juaneza, Municipality of Sara, Iloilo. The sanctuary, named after the native bamboo species Bambusa levis Blanco, is a 52 ha timberland area rich in avian life, endemic flora and fauna, and ecological diversity. Despite its natural assets, the sanctuary remains vulnerable due to the absence of formal protection and rehabilitation measures. Devastated by Typhoon Haiyan and now facing threats such as illegal hunting, tree burning, and habitat degradation, Sampunong Bolo lacks the local ordinances, infrastructure, and conservation programs necessary to protect its ecological integrity (Tupas, 2020). The migration patterns of herons—a keystone feature of the sanctuary—are disrupted by human activity, particularly from nearby fishpond operations, and no comprehensive biodiversity inventory or tourism development plan is in place.

The lack of legal designation, management interventions, and sustainable tourism frameworks underscores the critical need for collaborative efforts among the local government unit (LGU), the Department of Environment and Natural Resources (DENR), the Community Environment and Natural Resources Office (CENRO), and local academic institutions. Such partnerships are vital not only for the sanctuary's rehabilitation but also for exploring its potential as a community-based ecotourism destination.

It is in this context that this study was conceived. This research provides a systematic assessment of biodiversity in Sampunong Bolo Wildlife Sanctuary and evaluates its potential for sustainable tourism development. By identifying key species and ecological features, as well as the threats and opportunities present, this study offers evidence-based strategies for rehabilitation and sustainable management. The findings are expected to support policy formulation, guide conservation efforts, and inform tourism development initiatives led by LGUs, government agencies, environmental groups, and academic institutions.

Specifically, the study aims to answer the following research questions: 1). What are the diverse species of flora and fauna present within Sampunong Bolo Wildlife Sanctuary?, 2). What is the tourism potential of these species and the sanctuary's overall appeal?, and 3). What renovating and upgrading activities can address existing issues and rehabilitate the sanctuary? To achieve these objectives, this study will: 1).

Identify the diverse species of flora and fauna within Sampunong Bolo Wildlife Sanctuary, 2). Evaluate the tourism potential of these species and the sanctuary's overall appeal, and 3). Determine appropriate renovating and upgrading activities to address the issues and rehabilitate the sanctuary.

II. MATERIAL AND METHOD

A. Study Site/Location

The research was conducted in Sampunong Bolo Wildlife Sanctuary located in Barangay Juaneza, Municipality of Sara, Province of Iloilo, Philippines, from November 2021 to March 2022. This location is significant for its ecological importance and the presence of diverse faunal and floral species, making it a suitable site for studying tourism potential and sanctuary revival efforts. Geographically, the area is located at approximately 11.3159, 123.0205, in the island of Panay, Iloilo, Philippines. Elevation at these coordinates is estimated at 167.2 m (548.5 feet) above sea level. Juaneza shares a common border with barangays Castor, Tady, Ardemil, and Aguirre in the municipality of Sara, Iloilo, and barangays Talo-ato and Pangi in San Dionisio, Iloilo, Philippines (PhilAtlas, 2024). Sara has a tropical monsoon climate (Classification: Am). The district's yearly temperature is 27.92ºC (82.26ºF), and it is 0.7% higher than the Philippines's average. Sara typically receives about 85.28 mm (3.36 inches) of precipitation and has 150.08 rainy days (41.12% of the time) annually (Weather & Climate, 2024).

Primary data collection tools included a semi-structured interview guide featuring open-ended questions, along with recording devices (audio and video) used during interviews and focus-group discussions. Secondary data, such as an inventory of species, were obtained from the Department of Environment and Natural Resources-Community Environment and Natural Resources Office (DENR-CENRO). Thematic analysis software was utilized to assist in organizing and coding the interview transcripts.

The area was selected due to reports of its high biodiversity, including key species such as migratory birds and endemic flora. However, due to the absence of active field sampling by the researchers, biodiversity data in this study were sourced directly from the DENR-CENRO inventory, which did not disclose the detailed field methodologies or the temporal scope of data collection.

Figure 1. Google Map Image of Sampunong Bolo in Barangay Juaneza, Sara, Iloilo, Philippines

B. Methods

The study followed a mixed-methods research design, as outlined by Creswell and Creswell (2018). Using the purposesive sampling technique (Patton, 2014), 14 informants were selected based on their knowledge of the sanctuary and their capacity to provide relevant insights. These informants, consisting of barangay residents and officials, contributed to the study's two key data collection components. Primary data, including the tourism potential of various species and proposed renovation activities for the sanctuary, were collected through interviews and focus group discussions (Krueger, 2014). The interviews, conducted in person, were semi-structured to encourage detailed responses and were recorded with the informants' consent, then transcribed for analysis. Secondary data, such as species inventories, were sourced from the local DENR-CENRO office.

As the study relied on secondary biodiversity data from DENR-CENRO, the researchers did not conduct original field surveys to determine species composition, abundance, or seasonal variation. The absence of access to DENR-CENRO's sampling protocols limited the ability to analyze species distribution, habitat classification, or population estimates. Nonetheless, the species list provided valuable insights into the sanctuary's biodiversity profile. The evaluation of tourism potential was qualitative in nature and guided by the principles of sustainable ecotourism (Honey, 2008), focusing on observed attractions (e.g., avian diversity, natural landscape), accessibility, and informant perspectives.

C. Analysis

For data analysis, Thematic Analysis (Braun & Clarke, 2019) was employed to identify, analyze, and report patterns within the collected data. The analysis process involved several steps. First, the audio and video recordings were transcribed verbatim to ensure accuracy. The research team then familiarized themselves with the content by reading the transcripts multiple times. Next, initial codes were generated, highlighting significant features of the data. These codes were subsequently organized into potential themes, which were then reviewed and refined to ensure coherence. After finalizing the themes, each was clearly defined and named to capture the essence of the data. A detailed report was then written, presenting the themes supported by direct quotes from participants to illustrate key findings.

Since species data were descriptive and based on lists, no quantitative biodiversity indices (e.g., Shannon-Weiner, Simpson's Index) were calculated. The analysis of interview and focus-group data remained thematic and exploratory due to the limited sample size.

III. RESULT AND DISCUSSION

A. Faunal and Floral Species in Sampunong Bolo Wildlife Sanctuary

The secondary data obtained from the local DENR-CENRO revealed 39 faunal and 100 floral species, highlighting the area's rich biodiversity. Table 1 shows that the Sampunong Bolo Wildlife Sanctuary is home to a diverse range of faunal species, encompassing various groups. The faunal inventory includes 21 bird species, 2 mammals, 8 reptiles, 5 amphibians, and 3 arthropods. The sanctuary hosts a significant number of bird species, each contributing to the rich avian biodiversity of the area (Tupas, 2020). Mammalian species, though fewer in number compared to birds, are also present in the sanctuary. They contribute to the ecological balance and offer additional attractions for eco-tourists. Reptiles are another key component of the sanctuary's biodiversity, providing insights into the ecological interactions within the habitat. Amphibians are also indicators of environmental health and biodiversity, while arthropods play vital roles in the ecosystem, including pollination and nutrient cycling.

The presence of these faunal species highlights the rich biodiversity within the Sampunong Bolo Wildlife Sanctuary. This biodiversity not only underscores the ecological importance of the sanctuary but also presents significant opportunities for eco-tourism. Activities such as guided nature walks, educational tours, and wildlife photography can be developed to attract tourists while promoting conservation efforts. The collaboration with the local DENR-CENRO was instrumental in identifying these species. Their support and data provision were crucial in ensuring the accuracy and comprehensiveness of the biodiversity assessment.

While the conservation status of the documented species in Sampunong Bolo Wildlife Sanctuary was not explicitly indicated in the DENR-CENRO inventory, it is worth noting that Philippine wildlife includes many endemic and potentially threatened species due to habitat degradation and biodiversity loss. Given this, the sanctuary may serve as a crucial habitat for species of ecological concern, underscoring the importance of further biodiversity assessments and conservation planning in the area.

In contrast to fauna, the sanctuary's flora boasts a rich diversity of native trees, fruit-bearing plants, medicinal herbs, ornamentals, and aromatic species. This botanical diversity plays a crucial role in maintaining ecosystem stability and supporting wildlife habitats. A total of 100 floral species, as shown in Table 2, were recorded within the sanctuary. However, due to limitations in taxonomic expertise and reference materials, further classification into functional groups (e.g., native, medicinal, ornamental) could not be conducted. This highlights the need for collaboration with botanical experts in future studies to fully assess the ecological and tourism value of the area's flora.

The diverse flora of Sampunong Bolo Wildlife Sanctuary holds significant potential for tourism and recreation, offering opportunities for nature-based activities, educational tours, and aesthetic appreciation. Visitors can engage in botanical tours to learn about indigenous plants and their ecological roles, fostering a deeper appreciation for biodiversity

Table 1. Inventory of faunal species in Sampunong Bolo Wildlife Sanctuary

Groups	Species	Scientific names
Birds (Aves)	1. Olive-backed sunbird	*Cinnyris jugularis*
	2. Zebra dove	*Geopelia striata*
	3. Mountain white-eye	*Zosterops montanus*
	4. Philippine coucal	*Centropus viridis*
	5. Magnificent sunbird	*Aethopyga siparaja*
	6. Green-winged ground dove	*Chalcophaps indica*
	7. White-eared brown dove	*Phapitreron leucotis*
	8. Yellow-vented bulbul	*Pycnonotus goiavier*
	9. Philippine bulbul	*Hypsipetes philippinus*
	10. Crested serpent-eagle	*Spilornis cheela*
	11. Pied fantail	*Rhipidura javanica*
	12. Black-naped monarch	*Hypothymis azurea*
	13. Red jungle fowl	*Gallus gallus*
	14. White-breasted woodswallow	*Artamus leucorynchus*
	15. White-collared kingfisher	*Todiramphus chloris*
	16. Red turtle dove	*Streptopelia tranquebarica*
	17. Large-billed crow	*Corvus macrorhynchos*
	18. Brown shrike	*Lanius cristatus*
	19. Pink-necked green-pigeon	*Treron vernans*
	20. Glossy swiftlet	*Collocalia esculenta*
	21. Pacific swallow	*Hirundo tahitica*
Mammals	22. Palm civet	*Paradoxurus hermaphrodites*
	23. Malay civet	*Viverra tangalunga*

Groups		Species	Scientific names
Reptiles	1.	Amboina box turtle	*Cuora amboinensis*
	2.	Dog-tooth cat snake	*Boiga cynodon*
	3.	Reticulated python	*Malayopython reticulatus*
	4.	Green whip-snake	*Ahaetulla prasina*
	5.	Rough-necked water monitor	*Varanus salvator*
	6.	Dog-faced water snake	*Cerberus rynchops*
	7.	Philippine rat snake	*Coelognathus erythrurus*
	8.	Common wolf snake	*Lycodon capucinus*
Amphibians	9.	Whistling forest frog	*Platymantis dorsalis*
	10.	Cane toad	*Rhinella marina*
	11.	Bull frog	*Kaloula pulchra*
	12.	Common green frog	*Hylarana erythraea*
	13.	Philippine narrow-mouth toad	*Kaloula conjuncta*
Arthropods	14.	Millipede	*Thyropygus* spp.
	15.	Giant whip scorpion	*Mastigoproctus* spp.
	16.	Tailless whip scorpions	*Amblypygi* spp.

Source: Department of Environment and Natural Resources-Community Environment and Natural Resources Office (DENR-CENRO), Municipality of Sara, Iloilo, Philippines

conservation (Arkema & Ruckelshaus, 2017). Species with vibrant blooms and unique foliage provide picturesque settings for photography enthusiasts, enhancing the sanctuary's appeal as a scenic destination (Laplanche, 2023). Moreover, the sanctuary serves as a valuable site for environmental education and research, supporting studies on biodiversity conservation and sustainable land management (Gaston et al., 2008).

Effective conservation strategies are imperative to safeguard the sanctuary's flora diversity and enhance its role in sustainable tourism development. Habitat restoration efforts, including reforestation with native and fruit-bearing trees, are critical for maintaining habitat quality and promoting species diversity (Lindenmayer & Fischer, 2013). Community involvement in conservation initiatives is essential, fostering local stewardship and ensuring the sanctuary's long-term viability as a tourist destination (Khalid et al., 2019). Educational initiatives, such as interpretive signage and guided tours, can educate visitors about the ecological significance of flora species and encourage responsible behavior to minimize ecological impact (Poudel & Nyaupane, 2013).

To promote eco-tourism and raise environmental awareness, themed guided trails may be developed, such as a "Medicinal Plant Trail" showcasing traditional herbal species, or a "Native Tree Walk" highlighting indigenous flora important to local biodiversity. These trails can be supplemented with interpretive signage and guided tours to enhance visitor learning and engagement.

Table 2. Inventory of floral species in Sampunong Bolo Wildlife Sanctuary

	Species	Scientific names		Species	Scientific names
1.	Agoyangyang	*Abrus precatorius*	51.	Kauayan Kiling/ Lunas	*Bambusa vulgaris*
2.	Agpoi	*Phanera integrifolia*	52.	Kauyan tinik	*Bambusa blumeana*
3.	Alibangbang	*Bauhinia purpurea*	53.	Kawilan	*Bridelia stipularis*
4.	Alim	*Melanolepis multiglandulosa*	54.	Kubi	*Artocarpus nitidus*
5.	Amamali	*Leea aculeata*	55.	Lagundi	*Vitex negundo*
6.	Anagas	*Semecarpus elmeri*	56.	Lamio	*Dracontomelon edule*
7.	Anahau	*Livistona rotundifolia*	57.	Lampuyang	*Curcuma zedoaria*
8.	Anolang	*Papualthia lanceolata*	58.	Lanete	*Wrightia pubescens*
9.	Anonang	*Cordia dichotoma*	59.	Langka	*Artocarpus heterophyllus*

Species	Scientific names	Species	Scientific names
10. Antipolo	*Artocarpus blancoi*	60. Large-leaf Mahogany	*Swietenia macrophylla*
11. Anubing	*Artocarpus ovatus*	61. Libas	*Spondias pinnata*
12. Atis	*Annona squamosa*	62. Ligtang	*Anamirta cocculus*
13. Avocado	*Persea americana*	63. Lipata	*Kopeia fructicosa*
14. Bahobaho	*Ageratum conyzoides*	64. Lusegot	*Amydrium medium*
15. Balete	*Ficus balete*	65. Magabuyo	*Celtis luzonica*
16. Balinghasay	*Buchanania arborescens*	66. Makopa	*Syzygium samarangense*
17. Bamban	*Donax cannaeformis*	67. Malaikmo	*Calophyllum philippinense*
18. Banaba	*Lagerstroemia speciosa*	68. Malapaho	*Mangifera monandra*
19. Bangkal	*Nauclea orientalis*	69. Malapapaya	*Polyscias nodosa*
20. Bani	*Pongamia pinnata*	70. Malatungao	*Melastoma malabathricum*
21. Batino	*Alstonia macrophylla*	71. Mamalis	*Pittosporum pentandrum*
22. Bignai	*Antidesma bunius*	72. Mangga	*Mangifera indica*
23. Binunga	*Macaranga tanarius*	73. Marang	*Artocarpus odoratissimus*
24. Bogo	*Garuga floribunda*	74. Marang banguhan	*Litsea perrottetii*
25. Bolo or botong	*Gigantochloa levis*	75. Matang hipon	*Breynia vitis-idaea*
26. Buho	*Schizostachyum lumampao*	76. Neem	*Azadirachta indica*
27. Bunga	*Areca catechu*	77. Niyog	*Cocos nucifera*
28. Buri	*Corypha elata*	78. Niyog-niyogan	*Ficus pseudopalma*
29. Buta-buta	*Excoecaria agallocha*	79. Nito	*Lygodium circinnatum*
30. Cacao	*Theobroma cacao*	80. Nito puti	*Lygodium flexuosum*
31. Caimito/star apple	*Chrysophyllum cainito*	81. Oringon	*Cynometra mirabilis*
32. Chico	*Manilkara zapota*	82. Pagsahingin	*Canarium asperum*
33. Cogon	*Imperata cylindrica*	83. Pahutan	*Mangifera altissima*
34. Dita	*Alstonia scholaris*	84. Papaya	*Carica papaya*
35. False bird of paradise	*Heliconia bihai*	85. Putian	*Averrhoa javanica*
36. Gabi	*Colocasia esculenta*	86. Sablot	*Litsea glutinosa*
37. Galamay amo	*Schefflera odorata*	87. Saging-saging	*Aegiceras corniculatum*
38. Golden shower	*Cassia fistula*	88. Sambong	*Blumea balsamifera*
39. Guava	*Psidium guajava*	89. Sampalok	*Tamarindus indica*
40. Hauili	*Ficus septica*	90. Santol	*Sandoricum koetjape*
41. Igyo	*Dysoxylum gaudichaudianum*	91. Tagoang uak	*Croton leiophyllus*
42. Ilang-ilang	*Cananga odorata*	92. Takip asin	*Macaranga grandifolia*
43. Iloilo	*Aglaia argentia*	93. Takip kohol	*Centella asiatica*
44. Ipil-ipil	*Leucaena leucocephala*	94. Takipan	*Caryota rumphiana*
45. Kahoi dalaga	*Mussaenda philippica*	95. Talisai terminal	*Terminalia catappa*
46. Kalios	*Streblus asper*	96. Taluto	*Pterocymbium tinctorium*
47. Kamuning	*Murraya paniculata*	97. Tangisang Bayawak	*Ficus variegata*
48. Kaong	*Arenga pinnata*	98. Tisang-gubat	*Carmona retusa*
49. Kapok	*Ceiba pentandra*	99. Torch ginger	*Etlingera elatior*
50. Katmon baging	*Tetracera* sp.	100. Uvaria	*Uvaria rufa*

Source: Department of Environment and Natural Resources-Community Environment and Natural Resources Office (DENR-CENRO), Municipality of Sara, Iloilo, Philippines

B. Tourism Potential of Faunal and Floral Species in Sampunong Bolo Wildlife Sanctuary

The potential of the sanctuary to support eco-tourism development was explored through in-depth interviews with local informants. Based on their responses, three overarching themes emerged regarding the tourism potential of the faunal and floral species in Sampunong Bolo Wildlife Sanctuary (see Table 3): Theme 1 – Wildlife Observation, Theme 2 – Recreational Activities, and Theme 3 – Cultural and Economic Activities.

Theme 1: Wildlife Observation

Informants described the sanctuary as a historically popular site for birdwatching and faunal observation, particularly of species such as fruit bats and purple herons. One informant recalled,

"Years back, I remembered that the place was frequently visited by students and teachers from nearby schools, and from far and adjacent towns. There were lots of them coming here just to do some bird watching."

Another added,

"That's true, in the past it was nice and delightful to observe faunal species, especially those big 'kabog' (fruit bats) and 'dugwak' (purple herons)."

Wildlife observation is a central activity in ecotourism, offering opportunities for tourists to experience biodiversity in natural habitats (Tapper & Waedt, 2006). Research indicates that destinations rich in birdlife and other fauna attract eco-tourists and contribute to conservation and local economies (Shoo & Songorwa, 2013). These accounts highlight the site's potential to revive and expand wildlife tourism initiatives, especially birdwatching and nature photography.

Theme 2: Recreational Activities

Informants also noted that the sanctuary is an ideal setting for recreational activities such as picnics, trekking, and hiking. One shared,

"The presence of trees and plants enhances the place as a potential venue for picnics and relaxation. One can experience a serene and peaceful state of mind as the place is cool and calm due to the enormous shades of trees that protect people from the heat of the sun, and moreover, it is near to a stream."

Another stated,

"The place is not only good for picnics but also for trekking or hiking activities, as it is wide and features trails, and hilly and valley areas."

The sanctuary's cool, shaded environment and diverse terrain—characterized by streams, valleys, and natural trails—make it highly suitable for both leisure and low-impact adventure tourism. Recreational activities in natural settings are known to enhance mental well-being and physical health (Puhakka, 2021; Wicks et al., 2022; Wright, 2023). Additionally, studies have shown that well-maintained picnic grounds and hiking trails improve tourist satisfaction and encourage repeat visitation (Velmurugan et al., 2021). By enhancing these recreational offerings, Sampunong Bolo can attract nature-based tourists seeking both relaxation and exploration.

Theme 3: Cultural and Economic Activities

The sanctuary also holds value as a source of cultural heritage and local livelihood through its native plant resources. Informants highlighted the presence of kaong palm trees (Arenga pinnata), traditionally used for craft-making. One noted,

"Here in Sampunong Bolo, there are lots of 'hibyok or kaong palm trees'. Older residents and children made hand fans out of them, of which their finished products are then sold by them as a source of livelihood."

Another added,

"These palm trees that grow abundantly here may have potential that relates to tourism. Perhaps, this can be done if studies can be conducted to determine what other usages can be obtained from them."

These insights suggest opportunities for cultural tourism through craft-making, sustainable harvesting, and community-based enterprises. Cultural tourism, which includes engagement with local traditions and products, is a growing sector that supports both heritage preservation and economic resilience (Richards, 2018; Brown, 2020). Promoting locally made products and traditional knowledge could diversify the sanctuary's tourism offerings while reinforcing sustainable resource use and community involvement (Chan et al., 2021).

The three themes—wildlife observation, recreational use, and cultural livelihood—illustrate the sanctuary's multifaceted tourism potential. By promoting environmentally sensitive tourism activities that celebrate both biodiversity and local culture, Sampunong Bolo Wildlife Sanctuary can serve as a model for sustainable inland ecotourism in Northern Iloilo.

Table 3. Overarching themes, sub-themes, and actual responses of informants on the tourism potential of faunal and floral species in Sampunong Bolo Wildlife Sanctuary

Overarching themes	Sub-themes	Actual responses
1. Wildlife observation	1. Bird watching	*"Years back, I remembered that the place was frequently visited by students and teachers from nearby schools, and from far and adjacent towns. There were lots of them coming here just to do some bird watching."*
	2. Faunal observation	*"That's true, in the past it was nice and delightful to observe faunal species, especially those big 'kabog' (fruit bats) and 'dugwak' (purple herons)."*
2. Recreational activities	1. Picnics and relaxation	*"The presence of trees and plants enhances the place as a potential venue for picnics and relaxation. One can experience a serene and peaceful state of mind as the place is cool and calm due to the enormous shades of trees that protect people from the heat of the sun, and moreover, it is near to a stream."*
	2. Trekking and hiking	*"The place is not only good for picnics but also for trekking or hiking activities, as it is wide and features trails, and hilly and valley areas."*
3. Cultural and economic activities	1. Local craft and livelihood	*"Here in Sampunong Bolo, there are lots of 'hibyok or kaong palm tree'. Older residents and children made hand fans out of them of which their finished products are then sold by them as a source of livelihood."*
	2. Potential for new uses and studies	*"These palm trees that grow abundantly here may have potential that relates to tourism. Perhaps, this can be done if studies can be conducted to determine what other usages can be obtained from them."*

C. Renovating and Upgrading Activities to Rehabilitate Sampunong Bolo Wildlife Sanctuary

When asked about necessary efforts to rehabilitate and enhance Sampunong Bolo Wildlife Sanctuary, informants proposed a range of activities aimed at improving both its ecological integrity and appeal as a tourist destination. Their responses, as summarized in Table 4, revealed three overarching themes: Theme 1 – Policy and Regulation, Theme 2 – Infrastructure Improvement, and Theme 3 – Environmental Conservation.

Theme 1: Policy and Regulation

A critical concern raised by the informants was the lack of formal policies or ordinances protecting the sanctuary's rich biodiversity. One informant emphasized,

"For me, what is best here is that there should be a policy or barangay ordinance that could protect the place."

The absence of regulatory frameworks puts the area at risk of degradation. Implementing local policies or ordinances is vital to regulate human activities, prevent resource exploitation, and guide sustainable tourism development. Effective environmental governance at the community level can promote accountability, stewardship, and long-term conservation (Aall, 2014; Börner et al., 2020; Heyes, 2000). Moreover, community-based regulations—crafted with stakeholder participation—can empower residents and strengthen ecological resilience (Allgood et al., 2019; Lockwood, 2010).

Theme 2: Infrastructure Improvement

The need to enhance existing infrastructure emerged as a consistent recommendation among informants. One participant observed,

"If you have seen it, there are trails and concrete stairs that are still there. It's better that it should be enhanced and repaired to make the place more attractive."

The sanctuary's existing trails and stairs, if rehabilitated, can improve accessibility and visitor experience. Infrastructure such as well-maintained trails and facilities helps reduce environmental degradation by directing foot traffic and minimizing damage to sensitive areas (Leung et al., 2018).

Another informant noted,

"This place is naturally good for picnic activities, but people may come here more often if huts or cottages can be provided."

Providing visitor amenities like cottages or huts can encourage more frequent recreational use, increase tourist satisfaction, and extend visitor stays—leading to potential economic benefits (Akama & Kieti, 2003; Singh & Mishra, 2004). Additionally, the lack of signage was identified as a concern. One informant recommended,

"If there is signage, they should be placed at the site at once to serve as a warning and constant reminder for all to see and act accordingly relative to the protection of the place."

Strategic signage can guide visitor behavior, promote environmental awareness, and reinforce conservation messages. Educational and regulatory signs are proven tools in managing tourism impacts and supporting responsible visitation (Marschall et al., 2017).

Theme 3: Environmental Conservation

Informants also emphasized the need for reforestation and better utilization of natural resources. One shared,

"It is good also that more trees that birds like to stay with as their shelters be planted."

Tree planting, particularly of native species that provide food and shelter for wildlife, can significantly contribute to habitat restoration and biodiversity enhancement (Hails & Kavanagh, 2013; Di Sacco et al., 2021). Additionally, the sanctuary is abundant with kaong palm trees (Arenga pinnata), which locals use for making brooms and hand fans. One informant suggested,

"One more thing to consider is the presence of kaong palm tree which grows abundantly here. Besides using the palm trees to make fans or brooms, they can be further studied towards identification and development of more saleable products."

Exploring innovative and sustainable

Table 4. Overarching themes, sub-themes, and actual responses of informants on the renovating and upgrading activities to rehabilitate Sampunong Bolo Wildlife Sanctuary

Overarching themes	Sub-themes	Actual responses
1. Policy and regulation	1. Protection policies	*"For me, what is best here is that there should be a policy or barangay ordinance that could protect the place."*
2. Infrastructure improvement	1. Trail and stair enhancements	*"If you have seen it, there are trails and concrete stairs that are still there. It's better that it should be enhanced and repaired to make the place more attractive."*
	2. Facilities for visitors	*"This place is naturally good for picnic activities, but people may come here more often if huts or cottages can be provided."*
	3. Signage and information	*"If there is signage, they should be placed at the site at once to serve as a warning and constant reminder for all to see and act accordingly relative to the protection of the place."*
3. Environmental conservation	1. Tree planting	*"It is good also that more trees that birds like to stay with as their shelters be planted."*
	2. Utilization of kaong palm tree	*"One more thing to consider is the presence of kaong palm tree which grows abundantly here. Besides using the palm trees to make fans or brooms, they can be further studied towards identification and development of more saleable products."*

uses for the kaong palm could generate new livelihood opportunities and promote eco-friendly entrepreneurship. Developing value-added products from local resources is aligned with community-based sustainable tourism and can boost both conservation and economic development (Lantican & Haagen, 2014; Samal & Dash, 2023).

The three themes—policy formulation, infrastructure development, and environmental conservation—provide a roadmap for rehabilitating Sampunong Bolo Wildlife Sanctuary. A multi-pronged approach that integrates governance, visitor services, and ecological enhancement can transform the sanctuary into a resilient, attractive, and sustainable inland ecotourism destination.

IV. CONCLUSION

This study successfully identified the rich biodiversity of the Sampunong Bolo Wildlife Sanctuary, cataloging 39 faunal and 100 floral species. The findings demonstrate significant tourism potential through wildlife observation, recreational activities, and cultural and economic engagements. The sanctuary's history as a popular bird-watching site, particularly for species like fruit bats and purple herons, underscores its appeal to wildlife enthusiasts. Its natural environment, with cool, shaded spots and proximity to a stream, provides an ideal setting for picnics, relaxation, trekking, and hiking. Furthermore, the abundant kaong palm trees offer opportunities for local crafts and sustainable tourism, enhancing the sanctuary's attractiveness to culturally inclined tourists. The implications of this study are significant for LGU officials, DENR personnel, academicians, and other possible stakeholders. By highlighting the sanctuary's biodiversity and tourism potential, the study provides a roadmap for sustainable development that can benefit both the environment and the local community. The recommended renovating and upgrading activities, if implemented, can transform Sampunong Bolo into a premier ecotourism destination in the municipality of Sara, Iloilo, Philippines, promoting conservation and economic growth simultaneously.

V. LIMITATIONS OF THE STUDY

While this study provides valuable insights into the tourism potential of Sampunong Bolo Wildlife Sanctuary, several limitations should be considered when interpreting the findings. Firstly, the sample size for the interviews was relatively small, consisting only of key informants from the local community. To gain a more comprehensive understanding, future studies should include a broader sample, including visitors and external stakeholders, to provide a more holistic view of the sanctuary's tourism potential. Additionally, the study primarily relied on qualitative methods, which are inherently subjective. While qualitative insights are valuable for understanding perceptions and experiences, they may not fully capture quantitative aspects, such as species population densities, economic impacts, or visitor satisfaction.

Another limitation stems from the ecological data used in this study. Secondary data from the Department of Environment and Natural Resources (DENR) was used to create a species list. However, this data lacked detailed sampling protocols, abundance estimates, and consideration of temporal variation. A more robust field-based ecological assessment, including seasonal monitoring and detailed species distribution data, would be necessary to understand the sanctuary's biodiversity fully. The assessment of tourism potential was also limited by the absence of a structured framework. Basic visual and ecological criteria were used to evaluate the sanctuary's tourism appeal, but a comprehensive, established tourism evaluation tool would have enhanced the rigor and depth of the analysis. Furthermore, the study did not assess the infrastructure requirements for tourism development or conduct a detailed economic analysis of the potential costs and benefits, which are crucial for determining the feasibility and sustainability of proposed tourism initiatives.

Moreover, this study did not account for seasonal variations in biodiversity or tourism activities. Temporal differences in species presence and visitor patterns are important factors to consider for sustainable tourism planning. In addition, the study lacked essential environmental data, such as habitat quality or climate metrics, which would have provided further context for evaluating the sanctuary's tourism potential. Lastly, the research did not include a comparative analysis with other similar sanctuaries in the region. Such an analysis could have offered valuable insights into the unique features of Sampunong Bolo and its potential standing in the broader ecotourism landscape.

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PRODUCTIVITY AND ECONOMIC IMPACT OF BAMBOO IN MONOCULTURE VERSUS MIXED SYSTEMS: IMPLICATIONS FOR SOCIAL FORESTRY

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PRODUCTIVITY AND ECONOMIC IMPACT OF BAMBOO IN MONOCULTURE VERSUS MIXED SYSTEMS: IMPLICATIONS FOR SOCIAL FORESTRY. Bamboo forest holds significant potential for enhancing social forestry and community welfare. This study aims to compare bamboo's productivity and economic contribution in monoculture versus mixed systems in one of the village forests in Indonesia and analyze the implications for social forestry management. Using a quantitative approach with systematic sampling on 21 plots (14 monoculture plots, six mixed plots, and one pure shrub plot), data on bamboo 'clumps' (a group of bamboo plants that grow closely together) and 'culms' (the individual stems of the bamboo plant) dimensions and regeneration proportion were collected. Statistical analysis employed the Mann-Whitney U non-parametric test to compare two independent groups when the dependent variable is not normally distributed. Results showed that monoculture bamboo had higher productivity and economic contribution, averaging 6,374 culms per hectare per year and an estimated monetary value of IDR 50,992,000 per hectare per year, compared to 5,242 culms per hectare per year in mixed systems. Moreover, the monoculture system had a higher proportion of young bamboo (30.8%) than the mixed system (27.0%). Yet, the result shows the need to fairly balance economic benefits for the local community by strengthening the Management Institution of Village Forest (LPHD) in managing the bamboo supply chain. Implementing an agroforestry system that integrates bamboo with perennial plants and other non-timber forest products may also offer an effective solution for the local community, who cultivates bamboo plants on their own land. The implications emphasize government support in enhancing community capacity, providing market access, and regulations to promote sustainable practices in social forestry. Balancing productivity and sustainability in bamboo forest management can improve local welfare while maintaining forest ecosystems, aligning with Indonesia's social forestry objectives.

Keywords: bamboo, economic contribution, monoculture, agroforestry, production, village forest

PRODUKTIVITAS DAN DAMPAK EKONOMI BAMBU DALAM SISTEM MONOKULTUR DIBANDINGKAN CAMPURAN: IMPLIKASI UNTUK PERHUTANAN SOSIAL. Pengelolaan hutan bambu berpotensi mendukung program perhutanan sosial dan meningkatkan kesejahteraan masyarakat. Tujuan penelitian ini membandingkan produktivitas dan kontribusi ekonomi bambu pada sistem monokultur dan campuran di hutan desa, serta menganalisis implikasinya pada perhutanan sosial. Dengan pendekatan kuantitatif, diambil sampel sistematik pada 21 plot (14 plot monokultur, enam plot campuran, dan satu plot semak belukar), mencakup data rumpun, batang, dan proporsi regenerasi bambu, dan dianalisis dengan uji Mann-Whitney U. Hasil menunjukkan bahwa bambu monokultur lebih produktif dan memberikan kontribusi ekonomi lebih tinggi, dengan rata-rata 6,374 batang per hektar per tahun dan nilai ekonomi sekitar Rp 50,992,000 per hektar per tahun, dibandingkan dengan 5,242 batang per hektar per tahun dalam sistem campuran. Lebih jauh, sistem monokultur memiliki proporsi bambu muda lebih tinggi (30.8%) dibandingkan sistem campuran (27.0%). Namun demikian, hasil menunjukkan pentingnya menyeimbangkan manfaat ekonomi yang berkeadilan untuk masyarakat lokal dengan menguatkan peranan Lembaga Pengelola Hutan Desa (LPHD) dalam mengelola rantai pasok bambu. Implementasi agroforestri yang menggabungkan bambu dengan tanaman tahunan dan hasil hutan bukan kayu lainnya dapat menjadi solusi efektif untuk masyarakat lokal yang membudidayakan bambu

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di lahan miliknya sendiri. Implikasi penelitian ini menekankan perlunya dukungan pemerintah dalam meningkatkan kapasitas masyarakat, menyediakan akses pasar, dan menyesuaikan regulasi yang mendukung praktik pengelolaan bambu berkelanjutan. Keseimbangan antara produktivitas dan keberlanjutan dapat meningkatkan kesejahteraan masyarakat dan kelestarian hutan, sesuai dengan tujuan perhutanan sosial.

Kata kunci: bambu, kontribusi ekonomi, budidaya tunggal, agroforestri, produksi, hutan desa

I. INTRODUCTION

Sustainable forest resource management is a crucial global issue , especially when facing the challenges of deforestation, land degradation, and climate change. Uncontrolled forest exploitation has caused significant ecosystem damage, threatened biodiversity, and reduced the forest's capacity to provide ecosystem services, such as carbon sequestration and hydrological cycle regulation (Morán-Ordóñez et al., 2020). In addition to ecological impacts, forest destruction has socio-economic impacts, especially for local communities that depend on forest resources for their livelihoods (López-Carr, 2021).

In this context, social forestry has emerged as an alternative approach that integrates environmental conservation with improved local community welfare. Social forestry grants forest management rights to communities, assuming that active community participation can increase the effectiveness of conservation and provide direct economic benefits (Condro et al., 2022; Gunawan & Afriyanti, 2019; Kiss et al., 2022). In Indonesia, social forestry is implemented through various schemes, such as Village Forests (VF), Community Forestry (CF), Community Plantation Forests (CPF), Forestry Partnership (FP), and Customary Forest (CuF), to reduce poverty, create sustainable employment, and maintain forest sustainability (Ministry of Environment Forestry of the Republic of Indonesia, 2021; Fisher et al., 2019; Rodd et al., 2022; Octavia et al., 2022a; 2022b).

The social forestry approach is based on the theory of community participation in natural resource management. This theory emphasizes the importance of the local communities' involvement in decision-making and forest management to achieve ecological and socio-economic sustainability (Ballullaya et al., 2019; Kusumadewi et al., 2024; Laudari et al., 2024). Community participation is considered to increase a sense of ownership and responsibility for the sustainability of forest resources, which can reduce environmental destruction practices such as illegal logging (Kaskoyo et al., 2019). The concept of agroforestry serves as an essential theoretical framework for this study. Agroforestry is a land use system that combines forestry and agricultural practices to create a more productive, sustainable, and diverse system (Suparyana & Utama, 2023; Wong et al., 2020).

In the context of bamboo, agroforestry can increase land productivity by combining bamboo with other plants, and increase biodiversity and ecosystem function (Akoto et al., 2020). Similarly, understanding forest areas' carrying capacity and landscape potential, highlighted in studies on mountain-based destinations and national parks, provides critical insights for integrating conservation goals with sustainable management and forestry practices (Rahmafitria & Nurazizah, 2022). These balancing concepts are relevant in bamboo agroforestry.

The effective social forestry practices depend on the management systems, particularly in cultivating economically valuable species like bamboo. Bamboo cultivation has gained attention due to its rapid growth, versatility, and potential for ecological restoration and economic development (Ekanayake et al., 2021; Wong et al., 2020). Bamboo can contribute to soil stabilization, carbon sequestration, and biodiversity enhancement while providing material for construction, handicrafts, and other products (Akoto et al., 2020). In this regard, managing behavior and resource access can influence conservation outcomes and socio-economic benefits (Rahmafitria et al., 2024). For instance, insights from Komodo National Park, where conservation practices have been integrated with local community participation, highlight how sustainable management strategies can enhance ecological preservation and economic benefits. Such examples can guide the sustainable management of bamboo forests under social forestry schemes. However, the method of bamboo cultivation—whether through monoculture or mixed systems—can significantly influence these outcomes.

Previous studies have predominantly focused on the ecological aspects or general productivity of bamboo plantations without directly comparing monoculture and mixed systems within the context of social forestry (Minang et al., 2019; Yahya et al., 2022). This presents a research gap in understanding how different cultivation systems impact productivity and economic contribution, and their implications for sustainable forest management. Additionally, community readiness underscores the potential for integrating conservation-based forest management with tourist-driven economic opportunities (Rahmafitria et al., 2016).

Comparing monoculture and mixed bamboo cultivation systems is essential because each system offers distinct advantages and challenges that affect ecological sustainability and economic viability. Monoculture systems can maximize short-term financial returns with higher yields and simpler management. However, these systems often decrease soil fertility, increase pest vulnerability, and reduce biodiversity over time (Belete & Yadete, 2023; Rączkowska, 2019). In contrast, mixed systems integrate bamboo with other plant species, potentially enhancing ecosystem health, improving soil quality, and providing diversified income sources (Isukuru et al., 2023; Sulistyono et al., 2018). Even though agroforestry needs a more comprehensive approach and may gain slower economic returns, it offers long-term benefits, particularly in contexts where community livelihoods rely on forest resources. Understanding the trade-offs between these systems is critical for developing sustainable management practices that balance economic needs with ecological integrity, particularly in social forestry schemes.

Kutamanah Village Forest, located in Purwakarta Regency, Indonesia, is an example of the implementation of social forestry in Indonesia (Fiqri, 2023; Putra, 2021). Before being converted into a village forest, this area was a production forest managed by Perum Perhutani (an Indonesian state-owned enterprise responsible for forest management), with a dominance of Broadleaf Mahogany (S*wietenia macrophylla*) and Albizia (*Falcataria moluccana*). The transformation into a village forest gave management rights to the Management Institution of Village Forest (LPHD) of Kutamanah, which consists of local communities.

The community of Kutamanah Village Forest has long depended on apus bamboo, locally known as *bambu tali* (*Gigantochloa apus*), as a primary resource. While this species is used for various purposes in other regions, it is mainly harvested and sold only for building materials. Out of the 1,242 hectares of the village forest, *bambu tali* is intensively planted of 425.03 hectares. Bamboo cultivation in the village is predominantly done through a monoculture system rather than mixed planting. Economic considerations and easy management drive the community's preference for monoculture, as bamboo can be harvested quickly. However, this approach raises ecological concerns, including declined soil fertility, increased vulnerability to pests, and reduced biodiversity (Belete & Yadete, 2023; Rączkowska, 2019).

Historically, the area was not dominated by bamboo but by hardwood forests managed by Perum Perhutani, which restricted the community's access to the land. In response, the community began secretly planting bamboo among the hardwood trees. This mixed system that allowed bamboo to coexist with other plants is resulting in improved ecosystem health and diversification of income sources (Isukuru et al., 2023; Sulistyono et al., 2018). However, driven by economic incentives, bamboo planting became more intensive over time, ultimately leading to the dominance of bamboo in the area's land cover.

Although bamboo has significant economic and ecological potential, no in-depth study has compared the productivity and economic contribution between monoculture and mixed bamboo systems in the Kutamanah Village Forest. Previous studies have focused more on plants' ecological aspects or productivity in general, without directly comparing the two management systems in the context of social forestry. Therefore, this study aims to evaluate the potential and productivity of bamboo in monoculture and mixed systems within Kutamanah Village Forest. It also seeks to analyze the economic contribution of each system to the local community and identify the ecological impacts associated with each cultivation method. The research tries to fill the knowledge gap by comparing these systems and providing actionable recommendations for forest managers and policymakers. The main goal is to develop management recommendations to optimize the balance between economic productivity and ecosystem sustainability.

The urgency of this study is a comprehensive approach to the direct comparison between monoculture and mixed bamboo systems in social forestry. This study assesses the physical productivity of bamboo and considers economic contribution and ecosystem sustainability. This study also recommends forest management practices for improving the local communities' welfare and sustainability.

This study proposes an actionable move to develop social forestry policies in Indonesia. Policymakers may design effective and sustainable strategies by understanding the advantages and drawbacks of bamboo management systems. In addition, this study can also be a reference for other areas with similar conditions, both in Indonesia and other countries that implement social forestry.

II. THEORY

A. Social Forestry

Social forestry is a forest management approach that sets local communities as the main actors in the management and as the main beneficiaries of forest resources sustainably. This concept emerged as a response to the centralized forest management model that often ignores the rights and roles of local communities, which can lead to conflict and forest degradation (Maisaroh, 2022). Through social forestry, it is hoped that there will be an increase in community welfare as well as more effective forest conservation.

In Indonesia, social forestry has become one of the national strategies in forest management. Through the Ministry of Environment and Forestry, the government is targeting to allocate 12.7 million hectares of forest for the social forestry program (OID, 2016). There are five social forestry schemes, included Community Forestry (CF), Village Forest (VF), Community Plantation Forest (CPF), Customary Forest (CuF), and Forestry Partnership (FP). Kutamanah Village Forest is one example of a village forest implemented in Indonesia.

The implementation of social forestry in Indonesia faces various challenges, including tenure certainty, community capacity, and market access. Unclear land access and ownership rights often must be clarified for communities (Angessa et al., 2021; Nugroho et al., 2023). In addition, limited knowledge and skills in sustainable forest management are also challenges for local communities (Savari et al., 2020). Furthermore, restricted market access for communities makes it difficult to market forest products and obtain fair prices (Rochaedi et al., 2021). However, social forestry also offers opportunities for community participation in forest conservation, diversifies income sources, and strengthens local institutions (Fisher et al., 2019).

B. Bamboo Management

Bamboo is an economically and ecologically crucial non-timber forest resource. Globally, bamboo is used in the construction, handicraft, food, and energy industries (Ayer et al., 2023). In Indonesia, bamboo plays a significant role in the lives of rural communities as building materials, household appliances, parts of traditional customs, and sources of income (Yani & Anggraini, 2018).

Bamboo management can be carried out through two systems, namely monoculture systems and mixed systems (agroforestry). The bamboo monoculture system is carried out intensively without mixing with other plants. This system tends to increase bamboo productivity in the short term but can reduce biodiversity and soil fertility (Belete & Yadete, 2023; Rączkowska, 2019). Meanwhile, the mixed system is carried out by integrating bamboo planting with other plants, such as perennial trees or food crops. This system can increase biodiversity, soil fertility, and ecosystem sustainability (Isukuru et al., 2023; Sulistyono et al., 2018). Studies show that monoculture systems produce higher bamboo productivity per unit area than mixed systems (Akoto et al., 2020). However, based on the literature, mixed systems are more ecologically sustainable and can increase long-term income through product diversification (Bonilla, 2021).

In social forestry, bamboo management has the potential to improve community welfare. Fine management may optimize bamboo productivity and maintain environmental sustainability. Community participation in bamboo management can strengthen local institutions and forest management capacity (Maisaroh, 2022).

C. Economic Contribution of Bamboo

The bamboo industry has significant economic value globally (Lugt & King, 2019). In Indonesia, bamboo contributes to the local economy through the craft, construction, and tourism industries (Yani & Anggraini, 2018). Bamboo is also an essential source of income for rural communities, including in the Kutamanah Village Forest. However, optimizing the economic contribution of bamboo faces several challenges, such as limited technology and skills, market access and infrastructure, and policy support (Siddik, 2023). Limitations in processing technology and community skills hinder the development of added value for bamboo products, and these barriers even cause the Kutamanah community to be reluctant to switch to other forms of bamboo utilization. Several government agencies and non-governmental organizations have provided some training and assistance in increasing the added value of bamboo. However, the community still needs help accessing a broader market when the product is finished. This is what makes the community reluctant to change. The existing infrastructure, such as bamboo lamination machines, must be improved, as they are considered difficult to use.

Several steps are needed to increase bamboo's economic contribution and community capacity. Training and technical assistance in bamboo cultivation and processing must be continuously carried out to make the community aware and empowered (Akoto et al., 2020; Prilosadoso, 2018). The government and other stakeholders are responsible for developing market access for the local communities to market and promote their bamboo products (Buchari et al., 2023). The government may support the bamboo industry by making policies and regulations regarding incentives and business mentoring (Boissière et al., 2020).

D. Productivity of Bamboo

Bamboo, a versatile and fast-growing plant, has garnered attention for its potential to enhance land productivity, particularly in agroforestry. In Indonesia's social forestry, bamboo is recognized for improving the local communities' livelihoods and promoting environmental sustainability. As of 2005, Indonesia's bamboo forest spanned approximately 2.1 million hectares, with 0.69 million hectares within state forests and 1.41

million hectares on private or community lands (EBF, 2023; ITTO, 2025). The Indonesian government acknowledges bamboo's potential and prioritizes its social forest program development by initiating community forest and forest restoration. Bamboo can be cultivated in diverse ecosystems, including degraded lands, often unsuitable for traditional crops (Ihsan et al., 2023). Integrating bamboo into social forestry enhances local biodiversity and provides a sustainable income for rural communities (Hani et al., 2024).

Bamboo's ability to thrive in marginal lands allows for rehabilitating degraded areas, contributing to overall land productivity (Nigatu et al., 2020). The appearance of bamboo also results in significant soil quality improvement and carbon sequestration. It indicates an effective way to prevent climate change (Hani et al., 2024). This is particularly relevant in Indonesia, where the government promotes bamboo as a key component of reforestation and sustainable land management strategies.

The productivity of bamboo can be significantly influenced by the cultivation system employed. Studies have demonstrated that bamboo grown in agroforestry systems often exhibits higher productivity than monoculture systems. In some studies about the Land Equivalent Ratio (LER), a metric for assessing productivity difference, indicates that a LER value greater than 1.0 means that agroforestry systems are more productive per unit area than monocultures (Lehmann et al., 2020; Seserman et al., 2019).

Agroforestry systems benefit from the complementary relationships between bamboo and other crops. That kind of relation improves resource efficiency, for example, bamboo's deep roots can enhance soil structure, nutrient availability, and adjacent crops (Xu et al., 2023). Integration of bamboo and other crops benefits the ecological aspect (providing shade, reducing water competition, and enhancing land productivity) (Akoto et al., 2020), as well as the social aspect (diversifying locals' income and enhancing local wisdom). These advantages align with social forestry goals to promote sustainable land use and rural livelihoods. Conversely, monoculture bamboo plantations may be high-yielding but can lead to soil degradation and biodiversity reduction over a long period (Akoto et al., 2020).

E. Theoretical Framework and Relevance of the Study

Community Participation Theory in natural resource management is the basic theory in bamboo management in social forestry. This theory emphasizes that active community participation in natural resource management can increase the effectiveness of resource conservation and community welfare (Gunawan & Afriyanti, 2019; Kiss et al., 2022). Community involvement in bamboo management in social forestry can increase a sense of ownership and responsibility (Kaskoyo et al., 2019).

The concept of sustainable livelihoods is essential in this study due to its concern for integrating the economic, social, and environmental aspects. In bamboo management, it is necessary to balance the community's financial needs and the ecosystem's sustainability. Thus, the implications of this study emphasize the application of agroforestry principles. Agroforestry integrates trees with crops or livestock to improve land productivity and sustainability (Penkauskas et al., 2022; Octavia et al., 2022b). Bamboo agroforestry can increase biodiversity and provide additional economic benefits (Akoto et al., 2020; Kumar et al., 2014).

Although many studies have been conducted on bamboo management and social forestry, there is still a gap in understanding the direct comparison between bamboo productivity and economic contribution in monoculture and mixed systems, especially in Indonesia's social forestry context. This research is relevant because it can fill this gap, support policy, and improve optimal bamboo management practices.

This research tries to fill the knowledge gap by providing empirical data on comparing bamboo productivity and economic contribution in both management systems. Policy support from this research is also carried out by providing a scientific basis for formulating more effective social forestry policies. Through this research, LPHD or other institutions of bamboo management communities can improve bamboo management practices by utilizing practical recommendations to optimize welfare and sustainability.

III. MATERIAL AND METHOD

The study was conducted for six months, from January 2024 to July 2024, covering the planning stage, data collection, data analysis, and reporting of results.

A. Study Site

Kutamanah Village Forest was chosen as the research location because it represents the implementation of social forestry with two bamboo management systems: monoculture and mixed. This area is located within the geographical coordinates of approximately 107°18'0" to 107°22'0" E longitude and 6°30'0" to 6°32'0" S latitude, with an altitude between 120 m and 245 m above sea level. The area has a tropical climate with high levels of rainfall around 2,480 mm per year (BMKG, 2025). The temperature of Kutamanah ranges between 22°C and 32°C, providing suitable conditions for bamboo cultivation. Grey Alluvial and Red Latosol types dominate the soil in this area, which supports the growth of various kinds of bamboo.

B. Methods

This study employs a quantitative approach with a comparative descriptive design to evaluate the potential and productivity of bamboo in monoculture and mixed systems in Kutamanah Village Forest, Purwakarta Regency, Indonesia. A systematic sampling method was used by dividing the work area into 21 plots. Vegetation inventory began at Plot 1, then moved eastward and southward until reaching Plot 21 (Figure 1). Following forest inventory standards, the plot was 50×50 m (0.25 hectares) (Supriatna et al., 2021). The sampling intensity was 0.4%, adjusted based on available research resources. After inventory, of the 21 plots, 14 plots were identified as Monoculture Bamboo (BAM), and six plots were classified as Mixed Bamboo (BAX), while one plot was overgrown with pure shrubs, without any stands.

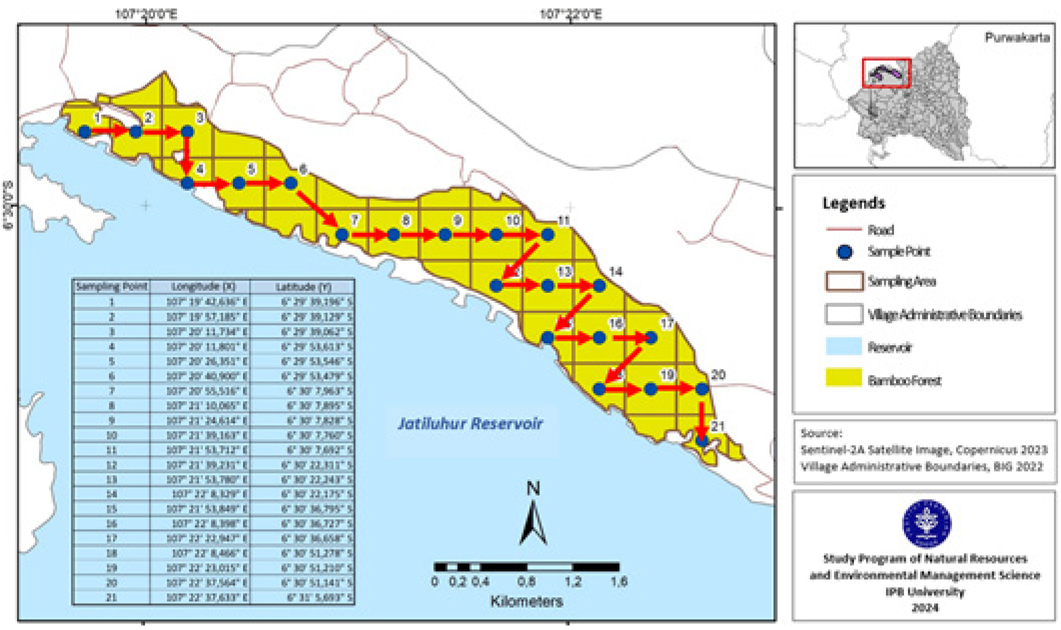

Figure 1. Location of Bamboo Forest sampling point, Kutamanah Village Forest, Indonesia

Data was collected through several stages, including image mapping, ground-checking and location validation, vegetation inventory, and environmental and social data collection. In the initial mapping, medium-resolution Satellite Imagery analysis from Google Earth Pro (2023) was carried out to identify land cover and bamboo distribution. Then, the land cover classification was done using a pixel-based digital classification method (unsupervised classification), referring to SNI 7645:2010. Furthermore, the plot location was determined using a GPS device with high accuracy and mapped using GIS software (ArcGIS).

The second step was ground-checking and location validation. This step is taken to validate the conformity between the satellite image and the actual condition in the field. Furthermore, adjustments were made to the plot location with accessibility constraints. The adjusted plot location was taken without reducing the representation of strata.

The third step in this study was vegetation inventory. This was carried out by measuring bamboo clumps (culm amount, circumference, and height of clumps) using a measuring tape at the clump's base and a clinometer for the height of the clump. Bamboo culm measurements were also carried out by counting the number of culms per clump, measuring culm diameter and height, and classifying age based on visual characteristics, including color sheen, sheath condition, surface texture, and the presence of white crust on the surface into mature, young, and bamboo shoots. Additionally, the culm condition was recorded as either intact or damaged.

Next, environmental and social data were collected to explore the physical conditions of the environment, such as land slope and soil type. Other vegetation was also identified, mainly perennial plants with a more than 10 cm diameter and other Non-Timber Forest Products (NTFPs). In-depth interviews were conducted with farmers and the Management Institution of Village Forest (LPHD) members regarding bamboo management and utilization practices, economic activities related to bamboo, and challenges faced in bamboo cultivation and marketing in the Kutamanah Village Forest. Respondents were selected purposively, starting with the chief of LPHD. Bamboo farmers were identified through recommendations by the LPHD chief or encountered in the field during bamboo sampling. A total of 3 LPHD members and seven bamboo farmers were interviewed. The parties, that represented diverse roles within the bamboo value chain, including (1) laborers who primarily harvest bamboo, (2) bamboo farmer who manage and harvest their bamboo, (3) transporter/middleman who own or rent transportation for bamboo logistics, and (4) bamboo wholesalers with direct links to sales outlets (material store).

Implementing steps such as training the research team, testing the measurement instrument, and data triangulation ensured the validity and reliability of this study. All members of the research team and enumerators underwent training on measurement methods, bamboo species identification, and data collection procedures to reduce observer bias. Instruments such as measuring tapes, calipers, and clinometers were calibrated before use. Field trials were conducted on test plots at IPB University to ensure that the instruments functioned properly and the team understood the measurement procedures. Data triangulation was conducted by comparing primary data from the field with secondary data from LPHD Kutamanah and information from the Forestry Services Branch II Purwakarta.

C. Analysis

The data analysis process in this study was carried out using SPSS version 25 and Microsoft Excel. The analysis stages include descriptive statistical analysis, normality test, hypothesis test, calculation of bamboo potential, bamboo productivity, economic potential, and sustainability analysis. Descriptive statistical analysis was carried out by calculating the mean, median, standard deviation, and coefficient of variation for each measurement parameter

Table 1. Normality test of clump and culm data using Kolmogorov-Smirnov Test

Clump	Kolmogorov-Smirnov			Culm	Kolmogorov-Smirnov		
	Statistics	Df	Sig.		Statistics	Df	Sig.
Category	.269	760	.000	Amount	.111	760	.000
Height	.179	760	.000	Diameter	.081	28,147	.000
Circumference	.075	760	.000	Height	.094	28,147	.000

(number of clumps, number of culms, culm height, culm diameter, and others), which was then continued by testing the normality of the data. The normality test used the Kolmogorov-Smirnov test to determine the distribution of the data. Since the data were not normally distributed (Table 1), the non-parametric Mann-Whitney U test was used to compare significant differences between the characteristics of the monoculture system and mixed systems' parameters.

The bamboo productivity and economic potential calculation is based on the number of mature culms ready for harvest per hectare. Then, productivity was multiplied by the market price of bamboo (IDR 5,000 per culm) to estimate the economic contribution per hectare per year. For the bamboo mixed system, due to the unavailability of data on the selling prices of perennial crops, the economic contribution will be estimated based on reference market prices. The calculation is conducted using the following formula:

Economic contribution per hectare per year =
BP × MP .... Formula 1

Note: BP = Bamboo productivity. MP = Market price (Farmer: IDR 2,500, Laborer: IDR 1,000, Middleman: IDR 1,500, Wholesaler: IDR 3,000

The principles of research ethics were followed in this study by asking for informed consent verbally. This is done by explaining the purpose and benefits of the survey to the Management Institution of Village Forest (LPHD) members and bamboo farmers. Their participation in interviews and data collection is based on voluntary willingness. Personal data and sensitive information are kept confidential, and the study results are presented without revealing individual identities.

In this study, researchers faced limitations, especially in the limited number of samples, other environmental variables, and the season and time of data collection. Limited time and resources cause the number of plots in the mixed system to be fewer than in monoculture, which may affect the generalization of the results. Then, factors such as clumps' density (Wirabuana et al., 2021), soil fertility, water availability, and sunlight exposure (the intensity of sunlight reaching the forest floor) were also not analyzed in depth, although they may affect bamboo productivity. In addition, the data collection time was unfortunately carried out two weeks after the primary harvest time, which may have affected the number of mature and young culms inventoried. Most of the mature culms had been harvested, so the proportion of regeneration appeared lower. Additionally, in this study, only bamboo vegetation was harvested. Other plants that Perhutani owns remain unharvested as they are not yet in their harvest cycle. According to local farmers and Forestry Services Branch II Purwakarta members, these plants will only be harvestable in approximately 10 years.

Consequently, this study did not calculate the economic potential of plants other than bamboo. Information on community preferences, market access, and other socio-economic factors was studied to a limited extent, so management recommendations may be less comprehensive. Therefore, the researcher's efforts to overcome these limitations were by analyzing the coefficient of variance and confidence intervals to assess the reliability of the estimates. In addition, field data were supplemented with notes on special conditions that could affect the results, such as previous harvest activities.

IV. RESULT AND DISCUSSION

A. Distribution of Bamboo Cover in Kutamanah Village Forest

Kutamanah Village Forest has a total area of 1,242 hectares. Based on the analysis of medium-resolution satellite imagery from Google Earth Pro (2023) and field surveys, land cover is dominated by the bamboo monoculture system (BAM) and the bamboo mixed system (BAX). The bamboo cover area reaches 425.03 hectares or around 34.22% of the total area (Figure 2). BAM dominates the total bamboo cover with 413.99 hectares, while BAX only covers 11.04 hectares.

The dominance of monoculture bamboo in Kutamanah Village Forest is due to the community's desire to cultivate G*igantochloa apus,* which is considered to have high economic value. In addition to *G. apus*, six other types of bamboo grow naturally, such as *G. verticillata*, *G. atroviolacea*, *G. atter*, *Dendrocalamus asper*, *Bambusa spinosa*, and *B. vulgaris var. vulgaris* and *B. vulgaris var. striata*, although in minimal quantities. The land cover analysis used satellite imagery data in 2018, 2020, and 2023. It also showed that granting management rights to the community in Social Forestry did not significantly change the forest coverage in Kutamanah during 2018-2023 (see Table 2).

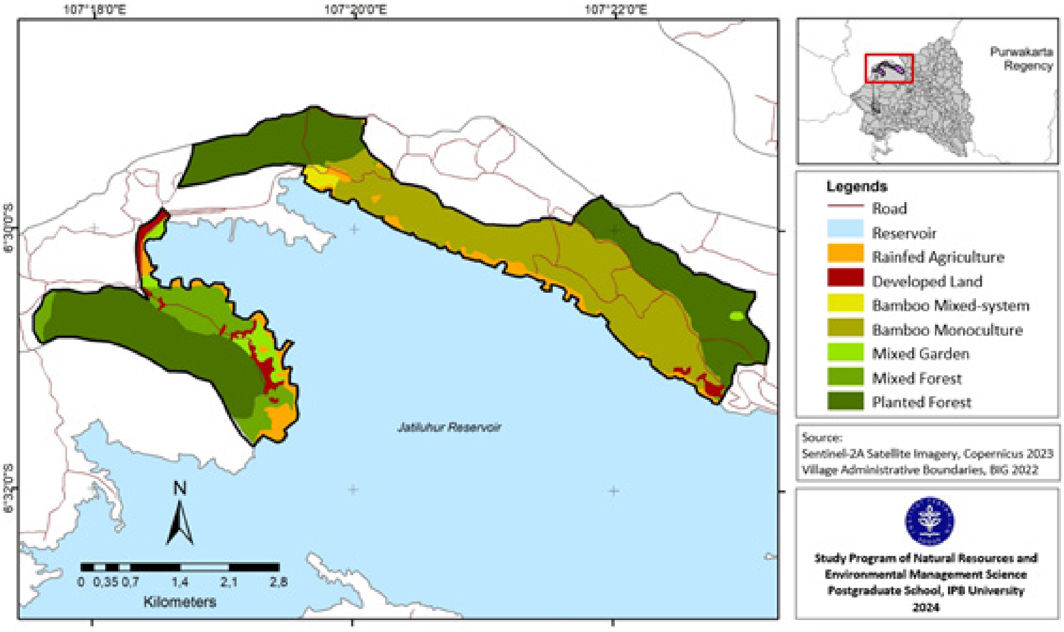

Figure 2. Land cover map of Kutamanah Village Forest in 2024

Table 2. Changes in land cover area of Kutamanah Village Forest in 2018, 2020, 2023

Land Cover	2018		2020		2023	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
BAM	407.08	32.78	415.10	33.42	413.99	33.33
BAX	32.14	2.59	32.14	2.59	11.04	0.89
Mixed Garden	27.67	2.23	29.65	2.39	31.07	2.50
Planted Forest	547.43	44.08	556.18	44.78	556.20	44.78
Mixed Forest	122.84	9.89	106.05	8.54	105.79	8.52
Developed Land	24.84	2.00	28.00	2.25	32.03	2.58
Rainfed Agriculture	80.00	6.44	74.88	6.03	91.88	7.40
Total	1,242.00	100.00	1,242.00	100.00	1,242.00	100.00

Remark: BAM = Bamboo Monoculture System, BAX = Bamboo Mixed System

The data indicates a slight fluctuation in the area covered by monoculture bamboo, increasing from 407.08 hectares in 2018 to 415.10 hectares in 2020, then marginally decreasing to 413.99 hectares in 2023. In contrast, the area under mixed bamboo cultivation significantly declined from 32.14 hectares in 2018 and 2020 to 11.04 hectares in 2023. This shift underscores a growing preference for monoculture systems among the local community.

The social tendency towards monoculture bamboo cultivation is economically motivated. *Gigantochloa apus* is highly valued in the local market due to its suitability for construction materials, rapid growth rate, and short harvest cycles. This aligns with the notion that economic incentives drive communities to practice a monoculture system for immediate financial gains (Belete & Yadete, 2023).

However, the dominance of monoculture systems raises ecological concerns. Monoculture plantations are associated with decreased soil fertility, increased vulnerability to pests and diseases, and reduced biodiversity (Rączkowska, 2019). The significant reduction in mixed bamboo areas suggests a loss of plant diversity, adversely affecting ecosystem resilience and function. Historically, mixed bamboo systems allow bamboo to coexist with hardwood species, contributing to improved soil health, enhanced biodiversity, and diversified income sources (Isukuru et al., 2023; Sulistyono et al., 2018).

The relatively stable forest coverage shows that the social forestry program prevents deforestation effectively. However, the quality of the forest ecosystem may be sacrificed due to the homogenous species. The reduced presence of other bamboo species and hardwoods diminishes habitat complexity, vital for supporting a wide range of flora and fauna (Ekanayake et al., 2021).

B. Differences in Characteristics of Monoculture and Mixed Bamboo Systems

Field inventory was carried out on 21 plots measuring 50×50 meters, consisting of 14 BAM plots and six BAX plots. The measurement results in each plot are presented in Table 3.

The average number of living culms per hectare for BAM is 5,366.2, for BAX is 3,737.8, and for the total area is 4,877.7. The findings highlight significant differences between the characteristics of monoculture and mixed bamboo systems. This research demonstrates that monoculture bamboo demonstrates superior productivity, with more clumps and culms per hectare, larger clump circumference, taller culm height, and greater culm diameter. The findings are consistent with bamboo research in Nepal (Thapa & Aryal, 2012) and applied to different bamboo species (Sharma et al., 2024). These observations provide initial evidence that monoculture systems prioritize bamboo yield.

Table 3. Characteristics of Bamboo Cultivation System

Plot no.	Bamboo cultivation system	Slope (%)	Altitude (m asl)	No. of clumps/ ha	Clump circum-fe-rence (cm)	No. of culms/ ha	No. of culms/ clump	Culm height (m)	Culm diameter (cm)	Other vegetation/ NTFPs
1	Shrubs	-	123	-	-	-	-	-	-	*Cassia fistula, Ficus hispida, Swietenia macrophylla, Kleinhovia hospital*
2	BAX	18	170	144	584	3,760	26.11	7.47	4.34	Shrubs
3	BAM	42	217	196	808	5,694	29.05	9.36	5.82	-
4	BAX	53	148	8	684	384	48.01	8.00	4.36	*Paraserianthes falcataria, Pterocarpus indicus*
5	BAX	78	185	156	723	7,126	45.68	7.30	4.71	Shrubs
6	BAM	60	215	180	693	3,866	21.48	9.09	5.79	-
7	BAX	36	160	128	765	4,862	37.98	8.34	4.94	Shrubs
8	BAM	53	177	180	708	5,391	29.95	9.62	5.15	-
9	BAX	42	205	188	580	5,259	27.98	8.33	4.63	*Dioscorea hispida, Tinospora crispa*
10	BAM	40	220	176	840	8,075	45.88	11.85	5.84	-
11	BAM	55	224	236	643	6,459	27.37	8.58	5.11	-
12	BAM	53	168	192	560	3,527	18.37	11.87	6.06	-

Plot no.	Bamboo cultivation system	Slope (%)	Altitude (m asl)	No. of clumps/ ha	Clump circum-fe-rence (cm)	No. of culms/ ha	No. of culms/ clump	Culm height (m)	Culm diameter (cm)	Other vegetation/ NTFPs
13	BAM	73	243	168	776	6,623	39.42	9.84	5.78	-
14	BAM	45	236	188	732	5,386	28.65	8.64	5.76	-
15	BAM	19	131	116	840	5,916	51.00	11.08	5.91	-
16	BAM	58	172	144	657	4,054	28.15	9.15	5.20	-
17	BAM	27	245	144	721	5,577	38.73	7.21	4.92	-
18	BAM	18	147	168	653	5,266	31.34	9.21	5.22	-
19	BAM	53	149	156	770	4,647	29.79	9.37	5.78	-
20	BAM	38	194	132	751	4,648	35.21	7.70	5.14	-
21	BAX	93	174	44	693	1,036	23.55	9.52	6.51	*Gliricidia sepium, Musa paradisiaca, Manihot esculenta*
Average of Total Area				152.2	709.0	4,877.7	33.2	9.08	5.35	
Average of BAM				169.7	725.1	5,366.2	32.5	9.47	5.53	
Average of BAX				111.3	671.4	3,737.8	34.9	8.16	4.91	

Remark: BAM = Bamboo Monoculture System, BAX = Bamboo Mixed System

Regarding the bamboo management system, the measurement results showed significant differences in the number of clumps, clump circumference, culms, culm height, and culm diameter (Table 4).

The measurement results further confirm the differences in productivity between monoculture and mixed bamboo systems. Monoculture bamboo consistently outperforms mixed systems in almost all key productivity parameters, including the number of clumps, clump circumference, number of culms, culm height, and culm diameter. The higher uniformity observed in monoculture bamboo, as reflected in the lower variability (standard deviation and coefficient of variation), suggests better regulation and resource allocation in this system. These findings emphasize the economic advantage of monoculture systems for communities that prioritize maximizing bamboo yield to meet market demands.

Notably, the number of culms per clump is higher in the mixed bamboo system. This phenomenon may be explained by differences in harvesting intensity and management objectives between the two systems. Monoculture systems, which are typically oriented toward commercial production, often undergo more frequent and uniform harvesting, resulting in a younger clump age structure and limiting the accumulation of culms. In contrast, mixed bamboo systems are generally subject to less intensive or more selective harvesting regimes, allowing culms to persist for extended periods. This accumulation over time contributes to a higher culm density per clump, despite the lower overall productivity observed in mixed systems.

The results of the Mann-Whitney U test showed that the differences were statistically significant ($p < 0.05$) for all parameters measured. Monoculture bamboo had more clumps and culms per hectare and better physical characteristics than mixed bamboo. The monoculture system allocates all available resources solely for bamboo growth. All resources, including space, nutrients, and water, are concentrated on bamboo development, resulting in superior physical characteristics of

Table 4. Comparison of bamboo characteristics between monoculture and mixed systems

Parameters	BAM	BAX	Total Area
The average number of clumps/ha	169.7 ± 15.33	111.3 ± 51.06	152.2 ± 22.07
The average circumference of clumps (cm)	725.1 ± 40.46	671.4 ± 54.63	709.0 ± 34.46
The average number of culms/ha	5,366.2 ± 609.61	3,737.8 ± 1,893.66	4,877.7 ± 782.17
The average number of culms/clumps	32.5 ± 4.48	34.9 ± 7.67	33.2 ± 3.92
The average height of culms (m)	9.47 ± 0.69	8.16 ± 0.58	9.08 ± 0.58
The average diameter of culms (cm)	5.53 ± 0.19	4.91 ± 0.59	5.35 ± 0.26

Remark: BAM = Bamboo Monoculture System, BAX = Bamboo Mixed System
Symbol ± represents 95% Confidence Intervals (CI), calculated using the Confidence function in Excel

Table 5. Results of the Mann-Whitney U Test on the characteristics of monoculture and mixed system bamboo

Variables	Ranks				Test Statistics		
	Bamboo Cultivation System	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Z	Asymp. Sig. (2-tailed)
Height of Clumps	BAM	594	415.21	246,637.5	28,681.5	-8.428	.000
	BAX	166	256.28	42,542.5			
Circumference of Clump	BAM	594	393.35	233,650.5	41,668.5	-3.053	.002
	BAX	166	334.52	55,529.5			
Number of Clumps	BAM	594	364.76	216,664.5	39,949.5	-3.741	.000
	BAX	166	436.84	72,515.5			
Diameter of Culms	BAM	21,122	15,554.57	328,543,522.0	42,918,531.0	-53.229	.000
	BAX	7,025	9,622.40	67,597,356.0			
Height of Culm	BAM	21,122	15,525.12	327,921,485.5	43,540,567.5	-52.422	.000
	BAX	7,025	9,710.95	68,219,392.5			

Remark: BAM = Bamboo Monoculture System, BAX = Bamboo Mixed System, N = sample size,
Z-value = standardized value used to test whether the difference between two groups is statistically significant

the bamboo (Mera & Xu, 2014; Zheng & Pacala, 2024). This indicates that the monoculture system is more effective in increasing bamboo productivity (Table 5).

Despite its advantages in productivity, monoculture systems may face ecological challenges in the long term. The statistical significance ($p < 0.05$) of the differences in all measured parameters underscores the efficiency of monoculture systems in enhancing bamboo yield. However, the ecological benefits of mixed systems—such as increased biodiversity, enhanced pest resilience, and greater ecosystem functionality (Belete & Yadete, 2023)—cannot be overlooked. These results suggest that while monoculture systems offer immediate economic benefits, they might compromise long-term sustainability without strategic interventions.

Field observations revealed that mixed bamboo plots show vegetation diversity, including Albizia, Mahogany, and non-timber forest products such as yam (*Dioscorea hispida*) and bitter vine (*Tinospora crispa*). This vegetation diversity adds ecological value, such as habitat creation and nutrient cycling, which is often limited in monoculture systems.

Furthermore, according to interviews with local farmers, the area, which was previously characterized by a heterogeneous composition of perennial vegetation, provided suitable habitat for a variety of wildlife species, including wild boars (*Sus scrofa*), barking deer (*Muntiacus muntjak*), forest-dwelling birds, and jungle cats (*Felis spp.*). Unfortunately, these species have been reported to have disappeared from the area since the shift toward a landscape dominated by monocultural bamboo stands. This suggests a significant reduction in habitat complexity and ecological niches, which aligns with broader evidence that intensive monoculture can lead to biodiversity loss and an ailing ecosystem (Belete & Yadete, 2023; Rączkowska, 2019). Combining agroforestry practices or a mixed planting system could mitigate the risks while promoting land productivity.

C. Bamboo Potential in Kutamanah Village Forest

The bamboo potential in Kutamanah Village Forest was analyzed to estimate the number of clumps and culms per hectare under monoculture (BAM) and mixed (BAX) systems. Table 6 presents the inventory data, revealing significant variability in the bamboo potential between the two systems. In BAM, the average number of clumps per hectare was 169.7 ± 15.33, while the average number of culms per hectare reached 5,366.2 ± 609.61. Conversely, in BAX, the average number of clumps per hectare was lower, reaching only 111.3 ± 51.05, with an average of 3,737.7 ± 1,893.66 culms/ha. The combined potential across the systems was calculated at 152.2 ± 22.07 clumps/ha and 4,877.7 ± 782.17 culms/ha, indicating the higher productivity of monoculture bamboo.

Table 6. Estimation of clump and culm numbers per hectare based on bamboo cultivation systems

Bamboo Cultivation Systems		Mean	SD	SE	% CV		CI
BAM							
	Clumps/ ha	169.7	29.27	7.82	17.24	±	15.33
	Culms/ ha	5,366.2	1,163.78	311.03	21.69	±	609.61
BAX							
	Clumps/ ha	111.3	63.81	26.05	57.31	±	51.06
	Culms/ ha	3,737.8	2,366.63	966.17	63.32	±	1,893.66
Total Area							
	Clumps /ha	152.2	50.37	11.26	33.09	±	22.07
	Culms/ ha	4,877.7	1,784.71	399.07	36.59	±	782.17

Remark: BAM = Bamboo Monoculture System, BAX = Bamboo Mixed System,
SD: Standard Deviation, SE: Standard Error, CV: Coefficient of Variation, CI: Confidence Interval

Monoculture bamboo shows consistent productivity with lower coefficients of variation (CV) in the number of clumps and culms per hectare. This uniformity is attributed to standardized planting practices and minimal competition from other vegetation, which enhances the efficiency of the monoculture system in regulating bamboo growth (Liu et al., 2018). In contrast, mixed bamboo systems display higher variability (CV values). This increased variability is likely due to other vegetation types, such as Albizia and various non-timber forest products (NTFPs), which, while contributing to ecological diversity, may compete with bamboo for resources. These findings align with another study on *Moso* bamboo (*Phyllostachys edulis*), which indicates that its expansion can intensify intraspecific and interspecific competition, potentially affecting growth dynamics within mixed forest stands (Chen & Bai, 2023).

Recalling that the total area is 425.03 hectares, with a monoculture bamboo area of 413.99 hectares and 11.04 hectares of mixed bamboo, the results of the potential estimation are as follows.

Estimated BAM area	=	70,254	±	6,346	clumps
	=	2,221,553	±	252,372	culms
Estimated BAX area	=	1,229	±	564	clumps
	=	41,265	±	20,906	culms
Estimated total area	=	64,690	±	9,380	clumps
	=	2,073,169	±	332,446	culms

The total potential of bamboo clumps and culms in the study area was estimated by extrapolating inventory data. The monoculture bamboo system, covering 413.99 hectares, was estimated to have 70,254 ± 6,346 clumps and 2,221,553 ± 252,372 culms. In comparison, the mixed bamboo system spanning 11.04 hectares was estimated to contain 1,229 ± 564 clumps and 41,265 ± 20,906 culms. The total bamboo potential in Kutamanah Village Forest was calculated at 64,690 ± 9,380 clumps and 2,073,169 ± 332,446 culms.

These findings demonstrate the trade-offs between the two systems. Monoculture bamboo provides higher productivity that aligns with the economic interests. However, the mixed bamboo offers ecological benefits through complex biodiversity. This supports previous findings from other studies that monoculture systems prioritize economic outcomes whilst mixed systems promote ecological resilience and diversity (Akoto et al., 2020).

Further, the results observed in monoculture bamboo systems support the idea of more predictable yields. However, this system sacrifices ecological diversity by neglecting habitat heterogeneity and soil quality. Conversely, the variability in mixed bamboo systems reflects a more dynamic ecosystem where bamboo coexists with other vegetation, providing additional ecological services such as carbon sequestration, soil stabilization, and habitat provision.

These results emphasize the importance of selecting bamboo management strategies based on short-term economic and long-term ecological sustainability goals. Incentive policies for communities that practice mixed systems may promote diverse vegetation while still meeting their financial needs. This intervention may mitigate the trade-offs between the two cultivation systems.

D. Bamboo Productivity and Economic Contribution

Analysis of the bamboo regeneration rate is essential to assess the sustainability of bamboo forest management. To ensure the regeneration, the ideal proportion of bamboo shoots is around 50% (Rahmadani et al., 2023). However, the results showed that the proportion of bamboo shoots in the Kutamanah Village Forest was relatively low (Table 7).

The shoot proportion can be considered relatively small in the research conducted on the Kutamanah Village Forest, because, based on literature, a proportion below 50% is considered small (Rahmadani et al., 2023). This can be seen from the unbalanced percentage of shoot, young, and mature bamboo. This also happens because data collection occurs two weeks after the primary harvest. Thus, the shoot proportion of this research is only 1.2%. Categorizing mature and young bamboo for inventory is challenging because most mature bamboo has been harvested, significantly affecting the proportion of regenerating bamboo. Thus, for this research, the shoot proportion gained from the proportion of bamboo shoots is 1.0% for BAM, 1.8% for BAX, and 1.2% for the total area.

In the Kutamanah Village Forest, bamboo farmers (consisting of 163 families listed in the 2023 Social Forestry Transformation Decree) are usually assisted by *Pelangsir* (bamboo transporters/middlemen) in bamboo harvesting activities. *Buruh* (bamboo laborers) help middlemen harvest bamboo for a fee of IDR 1,000 per culm, with a length of 6 meters. The bamboo farmers get IDR 2,500 per culm selling price from the middlemen. The middlemen then sold the bamboos to *Bandar* (bamboo wholesalers) for IDR 5,000 per culm. Then *Bandar* will sell for IDR 8,000 per culm to the building material stores, which have become partners in the city. Usually, the stores can sell bamboo at IDR 16,000 to IDR 25,000 per culm.

Bamboo productivity is calculated based on the shoot ratio and the number of mature culms per hectare, considering the selling price of bamboo. Estimating bamboo productivity (BP) can then be calculated to determine the estimated number of culms harvested yearly

Table 7. Proportion of bamboo regeneration in monoculture and mixed systems

Plot Name	Proportion of Bamboo (%)			Plot Name	Proportion of Bamboo (%)		
	Shoot	Young	Mature		Shoot	Young	Mature
Bamboo Monoculture System				**Bamboo Mixed System**			
Plot 03	1.5	46.2	52.4	Plot 02	0	20.4	79.6
Plot 06	0.1	42.9	57.0	Plot 04	0.8	34.6	64.7
Plot 08	0.9	28.8	70.3	Plot 05	1.6	30.1	68.3
Plot 10	0.7	29.2	70.1	Plot 07	1.7	24.3	74.1
Plot 11	0.5	31.5	68.0	Plot 09	1.3	26.5	72.2
Plot 12	1.7	39.9	58.4	Plot 21	5.7	26.1	68.2
Plot 13	0	21.8	78.2				
Plot 14	0.4	31.9	67.7				
Plot 15	3.9	27.0	69.2				
Plot 16	0.7	19.0	80.2				
Plot 17	1.2	22.5	76.3				
Plot 18	0.7	30.3	69.0				
Plot 19	0	33.5	66.5				
Plot 20	1.3	26.2	72.5				
Average	1.0	30.8	68.3	Average	1.8	27.0	71.2
Total Proportion				Shoot Bamboo	1.2 %		
				Young Bamboo	29.6 %		
				Mature Bamboo	69.1 %		

$$BP=(SR(\bar{x} \times MC)) \quad \text{.....Formula 2}$$

(Modified from Supriatna et al., 2021)

Table 8. Bamboo Productivity in Kutamanah Village Forest

	BAM	BAX
SR (bamboo shoot proportion)	1.0 %	1.8 %
$\bar{x}$ (no. of clumps per ha)	169.7 clumps/ha	111.3 clumps/ha
MC (mature clumps = harvest intensity × no. of culms/ha)	3,756.3 culms/ha	2,616.5 culms/ha
Harvest Intensity	70 %	70 %
Number of culms/ha	5,366.2 culms/ha	3,737.8 culms/ha
BP (Bamboo Productivity)	6,374.4 culms/ha/year	5,241.9 culms/ha/year

Remark: BAM = Bamboo Monoculture System, BAX = Bamboo Mixed System

per hectare. The considerations used are the value of the Shoot Ratio (SR), the average number of clumps per hectare ($\bar{x}$), and the number of mature culms (MC). However, based on bamboo's sustainable harvesting, the harvest intensity ratio will be 70% (Dransfield & Widjaja, 1995). Thus, the MC amount is calculated as the proportion of mature bamboo to the total number of culms. The formula is as follows, and the result is presented in Table 8.

For monoculture, the productivity values are 6,374 culms per hectare per year and 5,242 culms per hectare per year for mixed systems. Considering bamboo prices and those proportions, the estimated economic contribution of bamboo management for each party is presented in Table 9.

The potential economic contribution of BAM and BAX per year is IDR 21,573,151,520. The total numbers show the enormous economic potential of bamboo management in the Kutamanah Village Forest for all stakeholders. However, this potential has not been optimally utilized by the surrounding community. Until now, each bamboo farmer harvests 50 to 100 bamboo stalks per day, with 10-15 days of harvesting each month, so the amount obtained is around 1.25 to 2.5 million IDR per month, or up to 15 million IDR per year.

The economic benefits from bamboo cultivation in the study area remain below its potential. This shortfall is due to communities' limited engagement in optimizing the bamboo sector, particularly among bamboo laborers. A significant proportion of the productive-age population in Kutamanah tends to favor employment in the urban industrial sector, which is perceived to offer more stable income and better social mobility (Riggs et al., 2016). This labor migration aligns with broader rural development patterns in Indonesia and other Southeast Asian regions, where rural youth increasingly abandon agricultural work for factory jobs and service-sector employment in cities (Li, 2014).

Considering the conditions in the field, this can happen because, from the entire supply chain, wholesalers obtain the most significant benefits. Meanwhile, the bamboo farmers and laborers get a more limited proportion of economic benefits. Moreover, the middlemen's role is only controlled by a few people who can transport bamboo from the forest to the bamboo collection area. Not all middlemen act as wholesalers who have access to sell

Table 9. Bamboo Economic Contribution in Kutamanah Village Forest

Stakeholder/Role	Price/ culm (IDR)	Economic contribution/ha/year (IDR)		Economic contribution/year (IDR)		
		BAM	BAX	BAM (413.99 ha)	BAX (11.04 ha)	Total Area (425.03 ha)
Bamboo Farmers	2,500	15,935,000	13,105,000	6,596,930,650	144,679,200	6,741,609,850
Bamboo Laborers	1,000	6,374,000	5,242,000	2,638,772,260	57,871,680	2,696,643,940
Bamboo Middlemen	1,500	9,561,000	7,863,000	3,958,158,390	86,807,520	4,044,965,910
Bamboo Wholesalers	3,000	19,122,000	15,726,000	7,916,316,780	173,615,040	8,089,931,820
Total	8,000	50,992,000	41,936,000	21,110,178,080	462,973,440	21,573,151,520

bamboo to material stores, but all wholesalers are definitely middlemen. This shows that the community's capital, facilities, finances, access, and social position will affect the economic benefits derived from the bamboo potential in the Kutamanah Village Forest.

Furthermore, field observations revealed that even some bamboo farmers (individuals officially entrusted with managing land under the social forestry scheme) show limited interest in bamboo cultivation. In some cases, these individuals opted to transfer or lease their management rights to third parties in exchange for a lump-sum payment. This behavior is often driven by short-term consumer motivation, such as purchasing motorcycles, mobile phones, or household goods, rather than long-term investments in land-based livelihoods. Similar patterns have been documented in social forestry contexts elsewhere, where poor institutional support and unclear tenure arrangements reduce the incentive for sustainable resource management (Larson et al., 2010; Maryudi et al., 2021). This situation underscores the need for improved economic incentives, targeted training, and market access strategies to enhance community participation in sustainable bamboo management.

In addition, the mixed bamboo system in Kutamanah Village Forest incorporates other perennial tree species such as Albizia, which contribute supplementary economic value. Field observations across six mixed bamboo plots, each measuring 50 × 50 meters, identified 45 Albizia trees, equivalent to a density of 30 trees per hectare. Although these trees are not yet ready for harvest and are expected to reach commercial maturity over the next 10 years, they hold significant long-term value. Based on a local market price for Albizia logs with a diameter of 30–39 cm of IDR 600,000 per mature tree at the farmer level (Forestdigest.com, 2023), the total economic contribution of Albizia per hectare at harvest time is projected at IDR 18,000,000. When distributed over a 10-year harvest rotation, this equates to an annual supplementary economic contribution of IDR 1,800,000 per hectare. While modest compared to bamboo, this figure illustrates the economic diversification and resilience potential of integrating multipurpose tree species in agroforestry systems under community-based forest management.

LPHD's active role as a center in managing and distributing fairer benefits to local communities is significant. Suppose the overall process of optimal bamboo utilization can be made sustainable and fair. In that case, the economic benefits of the Kutamanah Village Forest community can be distributed more broadly and more effectively to its surrounding community, particularly if the total bamboo management uses a monoculture bamboo system. The value of productivity and its implications for economic contribution will undoubtedly be more significant. This is consistent with Isukuru et al.'s (2023) research, which states that the bamboo monoculture system can quickly produce a considerable amount of biomass.

However, some literature suggests that monoculture systems pose risks to ecosystem sustainability. Low biodiversity and a suboptimal proportion of bamboo regeneration can increase vulnerability to pests, diseases, and soil degradation (Belete & Yadete, 2023; Rączkowska, 2019). Mixed systems may be less productive economically, but offer ecological benefits regarding biodiversity and ecosystem functions (Isukuru et al., 2023; Sulistyono et al., 2018).

E. Implications in Social Forestry Management in Kutamanah

Social forestry aims to improve community welfare through sustainable forest management. The finding that monoculture bamboo is more economically productive shows the potential of bamboo as a leading commodity in social forestry. However, monoculture systems can threaten the sustainability of ecosystems due to the low biodiversity and the risk of soil degradation (Isukuru et al., 2023; Sulistyono et al., 2018). Therefore, forest management in social forestry schemes must consider the balance between economic productivity and ecosystem sustainability. Implementing a smart agroforestry system can be a solution that combines the advantages of both systems, increasing productivity while maintaining ecosystem function (Akoto et al., 2020; Octavia et al., 2022b). In addition, the results of this study encourage the government and stakeholders to develop policies that support the diversification of forest commodities and increase community capacity in sustainable forest management.

All management recommendations can be implemented to optimize the balance between economic productivity and ecosystem sustainability, especially those related to agroforestry systems, crop rotation arrangements, community capacity building, and market product diversification or service-sector employment

1. Implementation of a smart agroforestry system

   Integrating monoculture and mixed systems in balanced proportions can increase economic productivity while maintaining ecosystem sustainability (Octavia et al., 2022b). Planting perennial plants and other NTFPs with bamboo can increase biodiversity and ecosystem function while providing an additional source of income for the community (Akoto et al., 2020). Combining bamboo with leguminous plants such as Gamal (*Gliricidia sepium*) can improve soil fertility through nitrogen fixation. Furthermore, the potential for bamboo-based ecotourism can also be further explored, leveraging insights from studies on destination readiness and landscape potential to create value-added experiences that promote conservation and community engagement (Kusumoarto et al., 2017; Rahmafitria & Nurazizah, 2022).

   Some studies encourage smart agroforestry systems to increase economic value (Kumar et al., 2014; Octavia et al., 2022b). To maximize these benefits, a shift towards smart agroforestry practice is crucial. Smart agroforestry is an agroforestry model that integrates silvicultural and agricultural sciences to improve land productivity while ensuring ecological sustainability (Octavia et al., 2022b). It emphasizes applying best practices, including certified seeds and seedlings, SOP-compliant nursery systems, fertilization, pest and disease control, and regular maintenance to optimize plant growth and health. This approach promotes technology-based monitoring and structured planting schemes to improve economic outputs, particularly bamboo and companion crops in mixed systems. Implementing smart agroforestry in social forestry contexts like Kutamanah Village Forest can address underutilization of bamboo plant by enhancing community knowledge, increasing productivity, and encouraging long-term sustainable practices.

2. Crop rotation and clump conservation arrangements

   Conducting planned crop rotations and limiting logging intensity to 50% of the potential can ensure optimal bamboo regeneration (Rahmadani et al., 2023). However, the proportion of young culms in Kutamanah is only 29.6%, so the logging intensity becomes smaller. Increasing the proportion of bamboo shoots and young culms is necessary to ensure future bamboo resources. Clump maintenance and conservation should be undertaken to increase growth rates and ensure bamboo regeneration. Adopting conservation strategies in national parks, such as addressing human behavior in using or maintaining resources, may help enhance the effectiveness of bamboo forest management (Rahmafitria et al., 2024).

3. Product and market diversification

   The development of bamboo derivative products and other NTFP, as well as the modernization of processing technology, has excellent potential to increase added value and community income in the Kutamanah Village Forest. Drawing from successful examples of tourism destination management in protected areas, as well as ecotourism readiness studies, bamboo forests could be positioned as multifunctional landscapes that serve both conservation and tourism purposes (Kusumoarto et al., 2017; Nugroho et al., 2023; Nurazizah & Darsiharjo, 2018; Rahmafitria & Nurazizah, 2022). More comprehensive market access and an efficient supply chain will increase the competitiveness of bamboo products. The potential of bamboo forest ecotourism can also be developed as a community-based educational tourism destination, expanding income sources while introducing sustainable bamboo management. The main challenge is to change people's mindsets and encourage stakeholders to facilitate the adoption of infrastructure and policies that support the optimal use of bamboo and other NTFPs. Moreover, market development and value chain enhancement in social forestry will facilitate access to capital markets (Kumar et al., 2014).

4. Community capacity building in sustainable management

   Training and technical assistance to the community on sustainable forest management practices can increase productivity while maintaining ecosystem sustainability (Gunawan & Afriyanti, 2019). In addition, increasing community capacity in services-sector employment, such as ecotourism, is vital to support the diversification of bamboo use. With ecotourism training, the community can develop the potential of bamboo forests as educational tourism destinations offering forest tours, bamboo craft workshops, and promotion of other NTFPs. This will provide new, more diverse sources of income and strengthen public awareness of the importance of environmental sustainability.

5. Institutional strengthening

   Strengthening the Management Institution of Village Forest (LPHD) Kutamanah is very important to increase the effectiveness of forest management and community participation. This can be achieved through capacity-building for management, sustainable governance, and Pentahelix collaboration with governments, NGOs, academia, the private sector, and the community. The government can facilitate policies and funding, while the private sector helps expand markets and develop technologies for bamboo products and other NTFPs. NGOs and academics play a role in the training, while the community is taught about sustainable cultivation techniques. This institutional strengthening can also be supported by eliminating overlapping regulations (Nugroho et al., 2023). This support will improve people's welfare and open more comprehensive market access.

V. CONCLUSION

This study shows that the monoculture bamboo system in the Kutamanah Village Forest has higher productivity and economic contributions than the mixed bamboo. The productivity of monoculture is 6,374 culms/hectare/year, and the total economic contribution is

IDR 50,992,000/hectare/year. The numbers are much higher than the mixed system, which only reaches 5,242 culms/hectare/year and IDR 41,936,000/hectare/year. However, monoculture systems face challenges to ecosystem biodiversity, while mixed systems offer more ecological benefits with less economic productivity.

The implications of these findings emphasize the need to balance economic productivity and ecosystem sustainability in the social forestry program. Although monoculture systems are more economically beneficial, the risks to environmental sustainability need to be considered. Implementing smart agroforestry systems, crop rotation arrangements, community capacity building, and product diversification are recommended to balance economic productivity and ecosystem sustainability. The Kutamanah Village Forest may provide sustainable economic and ecological benefits with holistic participatory management.

The findings of this study provide important insights into bamboo forest management in social forestry schemes. Further research is recommended to increase the number and distribution of samples to improve resource management and sustainability effectiveness. An increase in the number of plots and a more even distribution between monoculture and mixed systems will increase the representativeness of the data. Future research may also consider analyzing other environmental and socioeconomic factors to provide a more comprehensive picture of the factors that affect the productivity and sustainability of bamboo management. In addition, long-term research is also needed to evaluate the impact of the implemented management recommendations and monitor changes in productivity and ecosystem conditions.

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COMPETITIVENESS OF PERUM PERHUTANI CAJUPUT OIL IN ACHIEVING SUSTAINABLE DEVELOPMENT GOALS IN THE FORESTRY SECTOR

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COMPETITIVENESS OF PERUM PERHUTANI CAJUPUT OIL IN ACHIEVING SUSTAINABLE DEVELOPMENT GOALS IN THE FORESTRY SECTOR. Cajuput (*Melaleuca cajuputi*) oil is one of the products developed under Perum Perhutani's Multipurpose Forestry Business. Developing the cajuput oil business remains a challenge; efforts must continue to build both competitive and comparative advantages and to increase revenue. The aim of this research is to analyze the competitiveness of Perum Perhutani's cajuput oil business which can be managed in accordance with the concept of sustainable development goals in the Forestry Sector. In doing this, we use Resources Based Value (RBV) and Value, Rarity, Imitability, and Organization (VRIO) analysis to evaluate the competitive resouces of cajuput oil bussines. SmartPLS was used to test the influence on achieving the Sustainable Development Goals (SDGs). The results show Perum Perhutani has sustainable competitive advantages, namely the quality of its cajuput oil plant seeds, the ability to achieve supply chain certification, and the ability to produce good quality products sustainably. In running the cajuput oil business, Perum Perhutaniexperiences a significant impact from applying SDG values, which manifest as both economic and ecological benefits.. Perhutani's cajuput oil products are more competitive than those of other domestic producers, but less competitive when compared to imported eucalyptus oil products in the global market.

Keywords: forest village communities, multipurpose forestry business, Partial Least Square (PLS), Resorces Based View (RBV), Value Rarity Inimitability and Organization (VRIO).

DAYA SAING MINYAK KAYU PUTIH PERUM PERHUTANI DALAM MENCAPAI TUJUAN PEMBANGUNAN BERKELANJUTAN DI SEKTOR KEHUTANAN. Minyak kayu putih (Melaleuca cajuputi) merupakan salah satu bisnis multi usaha kehutanan Perum Perhutani. Pengembangan model bisnis komoditas minyak kayu putih menjadi tantangan untuk dapat terus dikembangkan agar memiliki keunggulan kompetitif dan komparatif dalam rangka meningkatkan pendapatan. Tujuan dari penelitian ini adalah untuk menganalisis daya saing bisnis minyak cajuput Perum Perhutani yang dapat dikelola sesuai dengan konsep tujuan pembangunan berkelanjutan di Sektor Kehutanan. Dalam melakukan hal ini, kami menggunakan analisis Resources Based Value (RBV) dan Value, Rarity, Imitability, and Organization (VRIO) untuk mengevaluasi daya saing bisnis minyak cajuput. SmartPLS digunakan untuk menguji pengaruhnya terhadap pencapaian Tujuan Pembangunan Berkelanjutan (Sustainable Development Goals/ SDGs). Hasil penelitian menunjukkan Perum Perhutani memiliki keunggulan kompetitif yang berkelanjutan, yaitu kualitas bibit tanaman minyak kayu putih Perum Perhutani, kemampuan meraih sertifikasi rantai pasok, dan kemampuan menghasilkan produk yang berkualitas secara berkelanjutan. Dalam menjalankan bisnis minyak kayu putih, Perum Perhutani mendapatkan pengaruh nyata dari penerapan nilai-nilai SDGs berupa nilai ekonomi dan nilai ekologi. Produk minyak kayu putih Perhutani di pasar domestik memiliki daya saing yang tinggi, namun di pasar global memiliki daya saing yang rendah dibandingkan dengan produk Ekaliptus impor.

Kata kunci: masyarakat desa hutan, multi-usaha kehutanan, Partial Least Square (PLS), Resorces Based View (RBV), Value Rarity Inimitability and Organization (VRIO)

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I. INTRODUCTION

The existence of forests is deeply intertwined with human life due to their three essential functions: ecological, social, and economic. Utilizing a multi-product approach presents an appropriate solution for maintaining forest sustainability, as it distributes the ecological production process more evenly and lightly. Current forest management planning is designed to provide dual benefits to communities, enhance ecosystem resilience, improve water yield, protect against soil erosion, conserve biodiversity, promote tree growth and strength, and address the risk of natural disturbances (Baskent, 2018). In Indonesia, this complex approach to managing forest resource is referred to as MUK (Multi Usaha Kehutanan/ multipurpose forestry business).

The execution of MUK management activities is in accordances with the Sustainable Development Goals (SDGs). The SDGs aim to promote development that fosters sustainable growth through human rights and equality, while advancing social, economic, and environmental purposes (BAPPENAS, 2020). According to Ma et al. (2022), the SDGs benefit from ecosystem protection, restoration, and the sustainable use of forests, where the level of forest ecosystem service provision is key to supporting the SDGs. Indonesia has established an SDG Transition Secretariat within the Ministry of National Development Planning, categorizing the goals, targets, and indicators of the SDGs into social, economic, environmental, as well as legal and institutional governance pillars (Bastos-Lima et al., 2017). This study highlights how sustainable forestry practices can also drive economic competitiveness, especially through high-value products like cajuput oil that bridge environmental goals with market opportunities.

Competitiveness is all about how well a company can excel and stay ahead of its competitors. This involves using strategic advantages and managing resources effectively to achieve outstanding performance. That company success can come from either being the low-cost leader or offering something unique and valuable (Porter, 2011). Additionally, the Resource-Based View (RBV) emphasizes the importance of having rare and valuable resources (Barney, 1991). When applied to specific industries, these theories can shed light on how products like cajuput oil are making waves. Derived from the Melaleuca cajuputi tree, cajuput oil is gaining popularity due to its unique therapeutic benefits and versatility. Its rising prominence in health and wellness shows how specialized products can leverage their distinct features to stand out and succeed in a competitive market.

One of the companies that has the authority and capability to manage and ensure the implementation of MUK activities in a balanced manner is Perum Perhutani. According to Sianturi (2006), Perum Perhutani, as the operator of forest management activities, must be able to fulfill four essential elements: utilization, rehabilitation, protection, and conservation, in a balanced manner. Cajuput oil is one of Perum Perhutani's products with the potential to significantly contribute to both regional and national economic growth. Table 1 presents the cajuput oil production data of Perum Perhutani.

Tabel 1. Perhutani cajuput oil production data 2019-2023

Year	Production (tons)	Sales (tons)	Domestic Sales (IDR)	Overseas Sales
2019	325	322	85,556,000,000	-
2020	309	309	88,431,000,000	-
2021	346	323	98,996,000,000	-
2022	327	63	17,831,000,000	-
2023	181	33	7,120,000,000	-

Source: Perum Perhutani Annual Report 2019-2023

The production of cajuput oil at Perhutani has deacreased, particularly over the past two years, and has not yet be exported (Table 1). Rimbawanto et al. (2017) stated that the current domestic demand for cajuput oil is around 3,500 tons per year. Indonesia is only able to produce less than 500 tons per year, in which 30% of this amount supplied by Perhutani. This indicates that Perhutani plays a significant role in meeting the national demand for cajuput oil. Due to the supply-demand gap, Indonesia still imports eucalyptus oil to fulfill industrial needs.

Eucalyptus oil imports come from China, the United States, and Brazil, with China's import volume being the largest. The data on the realized eucalyptus oil imports from China to Indonesia are shown in Table 2. In 2019, 2020, 2021, 2022, and 2023, Indonesia imported 5.807 tons, 3.583 tons, 4.269 tons, 4.671 tons, and 3.766 tons, respectively, from China. The import amounted to $ 53.236.400 (2019), $ 47.255.966 (2020), $ 51.937.715 (2021), $ 54.188.137 (2022), and $ 31.693.394 (2023), with a total exceeding $ 240 million by the end of 2023. This situation is considered detrimental, as not only does it drain national foreign exchange reserves, but consumers also do not receive pure cajuput oil, which is a non-timber forest product (NTFP) that has a comparative advantage and is closely associated with forest-dependent communities (Rimbawanto et al., 2018).

According to Nilsson et al. (2016), promoting the sustainability of forestry, forests, and forest landscapes within the evolving bioeconomy is challenging due to the numerous high-level targets that are real, potentially conflicting, and sometimes divergent, as reflected in the SDGs. The design of a business in the agricultural sector has been widely carried out by researchers, including in the context of forestry production, and some of this has been researched in the Perhutani work area. Research on Timber Forest Product (TFP) and Non-Timber Forest Product (NTFP) business (Wijayanto et al., 2014), Jati Perhutani (Yanuarti et al., 2019), pine forest environmental services (Endratno et al., 2021), as well as cajuput oil products (Saptenno et al., 2022; Uktolseya et al., 2014; Octavia, 2019).The researcher's search indicates limited research on business for cajuput oil commodities.. Research on cajuput commodities is in the form of business feasibility analysis (Saptenno et al., 2022), production processes (Uktolseya et al., 2014), and cajuput oil business (Octavia, 2019). Research on cajuput business in Octavia's research (2019) which uses the BMC model approach is limited to local areas in Maluku and has not linked the design of cajuput business in order to achieve SDGs.No research has yet been found that examines the cajuput business on a broader scale and further from each indicator of the business model.. The development of the cajuput oil commodity business presents a challenge to continuously improve its

Tabel 2. Import realization of eucalyptus oil (HS 33012910) from China in 2019-2023

Year	Volume (tons)	Total Import Value (IDR)	Total Import Value (US$)
2019	5,807	752,261,386,566.67	53,236.400
2020	3,583	691,130,316,741.50	47,255.966
2021	4,269	745,042,193,532.08	51,937.715
2022	4,671	808,310,892,594.75	54,188.137
2023	3,766	482,333,839,937.50	31,693.394

Source: Indonesia Ministry of Trade 2019-2023 competitive and comparative advantage to increase the revenues of Perum Perhutani and the national income within the SDGs framework. Economic value, environmental value, social value, and institutional value are groups of SDGs values that can be considered in developing the sustainability of a business (Setianingsih et al., 2019; Rizky & Mashur, 2022). This study aims to analyzing the optimal key resources of Perum Perhutani's cajuput oil business, identifying which SDGs value factors influence the development strategy of Perum Perhutani's cajuput oil business.

II. MATERIAL AND METHOD

A. Time and Location

The research was conducted in August 2023. The study took place in five Forest Management Units (FMU) in Perum Perhutani. The selection of five FMU was based on indicators: a) representation of work units/FMU that have already developed the potential for cajuput oil commodity (FMU Madiun); b) representation of work units/FMU with cajuput oil potential still in the development process (FMU Tuban); c) representation of work units/FMU with limited cajuput oil potential but already developed (FMU Saradan); d) representation of work units/FMU with limited potential for cajuput oil and still in the development process (FMU Sukabumi); and e) representation of work units/FMU with very limited cajuput oil potential that has not yet been developed (FMU Pemalang).

B. Data Collection

The data used in this study consists of both primary and secondary data. Primary data were collected through measurements and observations, questionnaires, structured interviews, Focus Group Discussion (FGD), and in-depth interviews with key informants using the snowball sampling method for resources and capabilitites of Perhutani Cajuput oil. Meanwhile, to test the influence of SDGs on the cajuput oil business model Perum Perhutani used purposive sampling. Secondary data were gathered through the documentation of reports and data from relevant agencies, including Perum Perhutani, as well as supporting data related to the research found in the literature. Data validation was conducted using triangulation techniques. This research employs triangulation techniques for data collection by: (1) Comparing data from researchers and interviews; (2) Researchers compare data with what people say and what they personally say; (3) Researchers compare several data points from MKP Perhutani with those from other companies; (4) Researchers compare interview results regarding MKP Perhutani's internal resources with the contents of documents. Table 3 presents the main variables and data sources collected in this study.

Table 3. Variables and data sources collected

Variables	Indicators	Data Resources	Methods
Resources and capabilities of Perhutani Cajuput oil company	-Tangible resources -Intangible resources -Human resources -Capability	Researcher Observation and Interview of Cajuput oil Business Manager of Perum Perhutani	RBV & VRIO Barney, (1991)
SDGs value on Cajuput oil forestry business management in Perhutani	-Economic value -Social value -Environmental value, -Institutional value	Questionnaire with Cajuput oil Business Manager of Perum Perhutani Region, Farmers and Community Leaders	SEM - *PLS Analysis* (Ghozali, 2008)

Table 4. VRIO analysis framework for resources

Valuable (V)	Rare (R)	Inimitable (I)	Organization (O)	Implication
No (0)	No (0)	No (0)	No (0)	Competitive disadvantage
Yes (1)	No (0)	No (0)	Yes (1)	Balanced competitive
Yes (1)	Yes (1)	No (0)	Yes (1)	Temporary competitive advantage
Yes (1)	Yes (1)	Yes (1)	Yes (1)	Sustainable competitive advantage

C. Analysis

1) Resource Based View (RBV) and Valuable, Rarity, Imitability, Organization (VRIO)

RBV approach was used to evaluate the resources and competitive strategies of Perhutani's cajuput oil business including tangible and intangible resources. Tangible resources consist of cajuput silviculture and adequate infrastructure. Intangible resources include the quality of cajuput seedlings, the use of advanced technology, and the strategic location of the factory. According to Pearce and Robinson (2005), resources are divided into three categories: (1) tangible assets, which are the physical and financial tools used by a company to create value for customers; (2) intangible assets, which are invisible but often critical to achieving a competitive advantage; (3) organizational capabilities, which combine assets, people, and processes to transform inputs into outputs. This study incorporates these variables based on Pearce & Robinson, (2005) which are modified by adding a human resources variable was added as an asset to achieve competitive advantages. Human resources include the number of personnel, employee management, and a comfortable work environment. Organizational capabilities include the speed of sending and receiving raw materials, factory capacity, the ability to address current issues, warehouse capability, customer handling, product quality control, and human resource development.

Value, Rarity, Imitability, and Organization (VRIO) framework helps businesses determine whether their resources are not only valuable but also unique, hard for others to imitate, and well-managed to take full advantage of them. By evaluating resources through these lenses, companies can identify which assets are their strongest and how to use them effectively to stay ahead in the market and maintain a lasting competitive edge. The VRIO framework was applied to identify whether Perhutani's resources for the cajuput oil business represent weaknesses or strengths. The VRIO analysis framework is presented in Table 4.

2) Structural Equation Modeling (SEM) Analysis with Partial Least Square (PLS) Approach

PLS model analysis was conducted to assess the impact of Perhutani's cajuput oil business in relation to the SDGs in the forestry sector. The PLS model consists of two stages: the evaluation of the measurement model (outer model) and the evaluation of the structural model (inner model). The measurement model evaluation explains the relationship between the observed variable indicators, while the structural model evaluation explains the relationships between latent variables.

The number of respondents in this study was 362 respondents based on representation from five research locations: FMU Pemalang, Sukabumi, Saradan, Tuban, and Madiun. The minimum sample size for PLS-SEM should be equal to or greater than ten times the number of the largest formative indicators used to measure a single construct (Hair et al., 2011). According to Hair et al. (2011) the minimum number of respondents in this study was 60 people. respondents

The variables used in this study consist of latent variables and their corresponding indicators. In this research, the structural equation model was built to analyze how the latent variables (X) related to forestry—specifically, four out of the 17 SDGs latent variables—impact the field: economic value (X1), social value (X2), environmental value (X3), and institutional value (X4). The dependent variable (Y) was constructed based on competitiveness, consisting of Customer Segments (Y1), Value Propositions (Y2), Channels (Y3), Customer Relationships (Y4), Revenue Streams (Y5), Key Resources (Y6), Key Activities (Y7), Key Partnerships (Y8), and Cost Structure (Y9) (Government Regulations No: 59 2017; Presidential Decree No: 111 2022; Setianingsih et al., 2019; Rizky & Mashur, 2022).

a) Evaluation of measurement model (Outer model)

The measurement model is used to test the validity of variables and the reliability of indicators. Validity testing is carried out to determine the ability of research indicators to measure what should be measured. Convergent validity testing can be seen from the loading factor value and Average Variance Extrated (AVE). An indicator can be said to meet validity if the outer loading value is > 0.5. The AVE is considered sufficient if the correlation is between 0.5 and 0.6, and it is deemed high if the loading factor value exceeds 0.7(Ghozali 2008). The next validity test that can be used is discriminant validity. Discriminant validity is assessed based on the squared correlation value between the construct pairs. According to Ghozali (2008) the cross loading value for each variable must be > 0.70. Reliability testing can be carried out using the cronbach alpha and composite reliability criteria. A construct is declared reliable if the composite reliability has a minimum value of > 0.60 (Ghozali, 2008).

b) Structural model evaluation (Inner model)

Ghozali (2008) divides the R2 value into three categories, namely R2 value> 0.67 is categorized as a good model, 0.32 <R2 <0.66 is categorized as a moderate model and R2 <0.19 32 is categorized as a weak model. In addition, in the evaluation of the structural model, hypothesis testing (resampling bootstrapping) is also carried out. Hypothesis testing is carried out to see the significance between variables in the structural model. The statistical test used is the t-test. The hypothesis is accepted if the t-statistic value is greater than the t-table value with an alpha of 5%.

III. RESULT AND DISCUSSION

A. Key Resource Assessment of Perum Perhutani's Cajuput Oil Business

Based on the RBV analysis using the VRIO model and data collection through interviews, the results indicate that Perum Perhutani's cajuput oil business has advantages in several resources (Table 5). The competitors considered in the VRIO analysis are domestic competitors involved in cajuput oil production, namely cajuput oil from Maluku Province (Buru Island) and cajuput oil from Yogyakarta Forestry Service.

Table 5. VRIO Analysis Framework of Perhutani Cajuput oil with Domestic Cajuput oil

Resources	Description	V	R	I	O	Category
Tangible Resources	Production Facility					
	Cajuput oil production facilities	1	1	0	1	Temporary competitive advantage
Intangible Resources	Plant seed quality of Cajuput oil	1	1	1	1	Sustainable competitive advantage

Resources	Description	V	R	I	O	Category
Capabilty	Factory capability					
	Ability to produce good quality products	1	1	1	1	Sustainable competitive advantage
	Warehouse capability					
	Ability to maintain quality and quantity during storage	1	1	0	1	Temporary competitive advantage
	Product quality control					
	Ability to achieve supply chain certification	1	1	1	1	Sustainable competitive advantage
	Product quality control capability	1	1	0	1	Temporary competitive advantage
	Human resources improvement capability					
	Ability to improve employee competence	1	1	0	1	Temporary competitive advantage

A value of '1' for Value (V) indicates that the resource at Perum Perhutani is a 'valuable resource.' A value of '1' for Rareness (R) indicates that the resource at Perum Perhutani is a 'rare resource.' A value of '1' for Imitability (I) indicates that the resource at Perum Perhutani is 'a resource that cannot be perfectly imitated by competitors.' A value of '1' for Organization (O) indicates that the resource at Perum Perhutani represents 'organizational capabilities in managing resources to maximize their potential.' Meanwhile, a value of '0' indicates that Perum Perhutani lacks this attribute.

Based on data from the RBV & VRIO analysis, without looking at the declining state of Perum Perhutani's Cajuput oil, in fact Perum Perhutani's cajuput oil are three indicators showing 'sustainable competitive advantage' namely (1) the quality of Perum Perhutani's cajuput oil seedlings, (2) the ability to achieve supply chain certification, and (3) the ability to produce high-quality products. Currently, efforts to increase cajuput oil production at Perum Perhutani are being carried out through intensification (breeding cajuput plants to produce superior seeds) and extensification (expansion of cajuput plantations). The superior clones of cajuput oil seedlings—Clones 13, 39, and 71—are closely related to producing high-quality yields. This gives Perum Perhutani's cajuput oil business an advantage because it has superior seedlings that can be propagated by the company itself. These superior cajuput seedlings have better yields and a higher 1,8-cineole content (Prastyono et al., 2020). Cajuput oil production is a function of leaf production and oil yield. According to Prastyono et al. (2020), the larger the leaf production and the higher the oil yield from the leaves, the greater the oil production from the cajuput plants. Perum Perhutani's supply chain management capabilities are a competitive advantage for the cajuput oil business.

Cajuput leaves are harvested from cajuput plantations and transported to the cajuput oil factory for distillation, serving as the raw material for cajuput oil production. The cajuput oil is then stored at the cajuput oil factory warehouse for further processing and packaging. The capacity of each supplier and processor, the trucks for transportation, and the cost components of each operation in Perum Perhutani's cajuput oil business are carefully considered. According to Prastyono et al. (2020), the largest component of supply chain costs in the cajuput oil business in Rimbajaya Village, East Biak, is labor wages and firewood purchases for distillation, which account for 86% of the total costs. Meanwhile, Perum Perhutani is currently able to reduce distillation fuel costs by using briquettes made from dry cajuput leaf waste as a competitive advantage.

On the other hand, there are 'temporary competitive advantages' in four indicators namely (1) Perum Perhutani's cajuput oil production facilities, (2) the ability to maintain quality and quantity during storage, (3) the ability to supervise product quality, and (4) the ability to improve employee competencies. The company's capability to manage its business effectively is a factor that enhances quality and competitiveness. Perum Perhutani's capabilities in this regard are valuable resources that contribute to optimal quality (Table 8). Resources related to human resources and all other detailed indicators show 'balanced competition' when competing in the domestic market with cajuput oil Yogyakarta Forestry Service and cajuput oil Buru Island. So that cajuput oil Perhutani has good competitiveness, especially for the domestic market, but it has been destroyed by the low price of eucalyptus oil imports. If these conditions are not addressed, consumer preferences may shift toward eucalyptus oil in the long term. However, developing the cajuput oil industry is actually more efficient in terms of foreign exchange, and more beneficial socially and environmentally.

B. SDGs Value Factors in the Development of Perum Perhutani's Cajuput Oil Business Model

1) Evaluation of the Reflective Measurement Model

The loading factor value for all indicators is considered valid if it is greater than 0.7, and the AVE value is acceptable if each construct has a value greater than 0.5 (Avkiran & Ringle, 2018). An AVE value greater than 0.5 means that 50% or more of the variance of the indicators must be accounted for. Internal consistency is measured using Cronbach's alpha and composite reliability. A Cronbach's alpha and composite reliability value greater than 0.70 is used as a benchmark for reliability, particularly in the early stages of research (Vinzi et al., 2010). The AVE, Cronbach's alpha, and composite reliability values for all variables in this study meet the required thresholds, meaning that each indicator used in this study can be used for further structural testing (Table 6). In the other, discriminant validity, according to Fornell and Larcker (1981), the AVE value exceeds the squared correlation value between the construct pairs (Table 7).

Table 6. Convergent validity and reliability testing

Constructs	Loading factor	AVE	Composite reliability	Cronbach's alpha
Economic value (X1)		0.606	0.902	0.869
Community Income	0.776			
Perhutani Income	0.748			
Providing employment opportunities	0.829			
New economic opportunities	0.799			
Market Access	0.808			
Infrastructure Improvement	0.704			

Constructs	Loading factor	AVE	Composite reliability	Cronbach's alpha
Social Value (X2)		0.645	0.845	0.726
Addressing poverty levels	0.823			
Improving Formal Education	0.801			
Improving Food Security	0.785			
Environtmental Value (X3)		0.593	0.853	0.773
Soil fertility	0.811			
Natural disaster reduction	0.777			
Climate responsive society	0.763			
Community participation in protecting forests	0.725			
Institutional Value (X4)		0.854	0.921	0.828
Community group companion	0.924			
Business and area governance	0.924			
Customer Segments (Y1)		1.000	1.000	1.000
Diversified market segmentation	1.000			
Value Proportion (Y2)		0.586	0.876	0.822
Design	0.704			
Cost Reduction	0.760			
Risk Reduction	0.858			
Accessibillity	0.743			
Convenience	0.753			
Channels (Y3)		0.609	0.862	0.786
Awarness	0.755			
Evaluation	0.769			
Purchase	0.798			
Delivery	0.799			
Customer Relationships (Y4)		0.619	0.907	0.877
Personal Assistance	0.834			
Dedicated Personal Assistance	0.756			
Self Service	0.752			
Automated Service	0.763			
Communities	0.806			
Co-creation	0.806			
Revenue Streams (Y5)		1.000	1.000	1.000
Asset Sale	1.000			
Key Resources (Y6)		0.710	0.907	0.864
Physical	0.842			
Intellectual	0.855			
Technology	0.836			
Channel	0.837			
Key Activities (Y7)		0.783	0.878	0.725
Production	0.858			
Problem Solving	0.910			

Constructs	Loading factor	AVE	Composite reliability	Cronbach's alpha
Key Partnerships (Y8)		0.607	0.861	0.784
Alliance	0.776			
Competition	0.805			
Joint venture	0.803			
Buyer-supplier relationship	0.732			
Cost Structure (Y9)		0.652	0.882	0.821
Fix cost	0.760			
Variable cost	0.804			
Cost-driven	0.868			
Value-driven	0.794			

Tabel 7. Discriminant validity testing.

	Y7	Y5	Y4	Y8	X1	X4	X3	X2	Y2	Y3	Y1	Y9	Y6
Y7	**0.885**												
Y5	0.518	**1.000**											
Y4	0.759	0.470	**0.787**										
Y8	0.665	0.431	0.707	**0.779**									
X1	0.520	0.580	0.475	0.405	**0.778**								
X4	0.359	0.446	0.326	0.448	0.608	**0.924**							
X3	0.523	0.558	0.559	0.532	0.687	0.490	**0.770**						
X2	0.482	0.504	0.346	0.395	0.739	0.540	0.698	**0.803**					
Y2	0.531	0.539	0.667	0.546	0.659	0.443	0.702	0.598	**0.766**				
Y3	0.577	0.525	0.650	0.472	0.715	0.488	0.642	0.615	0.765	**0.780**			
Y1	0.368	0.422	0.443	0.338	0.478	0.360	0.584	0.459	0.528	0.516	**1.000**		
Y9	0.760	0.625	0.742	0.641	0.644	0.444	0.587	0.563	0.668	0.664	0.411	**0.807**	
Y6	0.740	0.503	0.809	0.656	0.541	0.380	0.550	0.468	0.662	0.697	0.431	0.772	**0.842**

Remark: economic value (X1), social value (X2), environmental value (X3), and institutional value (X4). The dependent variable (Y) was constructed based on competitiveness, consisting of Customer Segments (Y1), Value Propositions (Y2), Channels (Y3), Customer Relationships (Y4), Revenue Streams (Y5), Key Resources (Y6), Key Activities (Y7), Key Partnerships (Y8), and Cost Structure (Y9)

2) Structural Model Evaluation

The evaluation of the structural model involves testing the hypotheses regarding the influence between research variables, which is conducted in three stages. First, multicollinearity between variables is examined using the inner Variance Inflated Factor (VIF) measurement. An inner VIF value above 5 indicates multicollinearity issues between variables (Hair et al., 2021). The inner VIF values in this study meet the required standards (Table 8).

Second, if the t-statistic is greater than the t-table value or if the p-value of the test is less than 0.05, there is a significant influence between variables with a 95% confidence interval. Significant relationships can be seen in Table 9. Third, the f-square value is used to assess the direct influence of a variable at the structural level, with the following criteria: $0.02 \leq f \leq 0.15$ = low, $0.15 \leq f \leq 0.35$ = moderate, and $f \geq 0.35$ = high (Hair et al., 2014).

Table 8. Inner VIF Values

	Economy (X1)	Institution (X4)	Environment (X3)	Social (X2)
All dependent Variables	2.829	1.641	2.239	2.641

Remark: All dependent Variables: From Y1-Y9

Based on the results of the tests, the management of Perhutani's cajuput oil business has considered environmental aspects in every operational activity, including at the factory or in marketing management. In the social context, only the customer relationship indicator is related to cajuput oil business management, and most other operational business indicators do not address social values. This implies that Perhutani's activities in the cajuput oil business involve customers (buyers of cajuput oil) in creating social value, as indicated by helping reduce poverty and improving food security in forest village communities. Similarly, institutional value in the cajuput oil business is only influenced by indicators related to revenue streams and key partners, indicating that Perhutani's support for community groups in forest villages as business partners has a positive impact on Perum Perhutani's revenue.However, economic value in the cajuput oil business does not influence customer segmentation or key partners, but it does influence other indicators. The economic value of Perum Perhutani's cajuput oil business has not yet expanded geographically or to the export market, and it remains limited to the domestic market in Indonesia. Moreover, the buyer-supplier relationship between Perum Perhutani and its customers has not yet shown strong connections, as evidenced by the replacement of cajuput oil purchases with imported eucalyptus oil.

Table 9. P-Value, T statistics and F-square

	T statistics (|O/STDEV|)	P values	F-Square	Desc.
Economic Value (X1) -> Key Activities (Y7)	2.067	0.039	0.032	low
Economic Value (X1) -> Revenue Streams (Y5)	2.691	0.007	0.052	low
Economic Value (X1) -> Customer Relationship (Y4)	2.119	0.034	0.040	low
Economic Value (X1) -> Value Proportion (Y2)	3.146	0.002	0.074	low
Economic Value (X1) -> Channels (Y3)	4.876	0.000	0.168	moderate
Economic Value (X1) -> Cost Structure (Y9)	3.744	0.000	0.101	low
Economic Value (X1) -> Key Resources (Y6)	2.497	0.013	0.045	low
Institutional Value (X4) -> Revenue Streams (Y5)	2.157	0.031	0.013	-
Institutional Value (X4) -> Key Partnerships (Y8)	3.730	0.000	0.068	low
Environmental Value (X3) -> Key Activities (Y7)	2.525	0.012	0.051	low
Environmental Value (X3) -> Revenue Streams (Y5)	3.023	0.003	0.056	low
Environmental Value (X3) -> Customer Relationship (Y4)	5.103	0.000	0.186	moderate
Environmental Value (X3) -> Key Partnerships (Y8)	4.587	0.000	0.139	moderate
Environmental Value (X3) -> Value Proportion (Y2)	5.756	0.000	0.203	moderate
Environmental Value (X3) -> Channels (Y3)	3.858	0.000	0.064	low
Environmental Value (X3) -> Customer Segmentation (Y1)	4.802	0.000	0.152	moderate
Environmental Value (X3) -> Cost Structure (Y9)	2.494	0.013	0.047	low
Environmental Value (X3) -> Key Resources (Y6)	3.170	0.002	0.075	low
Social Value (X2) -> Customer Relationshi (Y4)	2.720	0.007	0.032	low

3) Evaluation of the Reflective Measurement Model

The model fit evaluation can be assessed using R-square, SRMR, and NFI. The coefficient of determination (R-square) is used to measure the degree of variation in the independent variable's influence on the dependent variable and to empirically assess the 'goodness of fit.' According to Ghozali, (2008), the R^2 value is categorized into three levels: $R^2 > 0.67$ indicates a good model, $0.32 < R^2 < 0.66$ indicates a moderate model, and $R^2 < 0.19$ indicates a weak model. The R-square values for this study's model can be seen in Table 10. According to Yamin (2021), the model is still considered fit and acceptable if the SRMR value is less than 0.08. Meanwhile, the closer the Normal Fit Index (NFI) is to 1, the better the model.

The R-square values in this study range from 0.326 to 0.558. According to Ghozali (2008), all of these models fall within the moderate category. This means that 33% to 56% of Perum Perhutani's management of the cajuput oil business is influenced by economic, social, environmental, and institutional values. Another external factors that are thought to affect cajuput oil business management include market demand, government policies in supporting cajuput oil business, supporting institutions managing cajuput oil trade, and low export value of cajuput oil compared to other essential oils (Utami et al., 2023). Meanwhile, management factors within the company itself can also be a factor such as quality, total revenue, and markets as the main factor (Rahmayanti et al., 2022). The data processing results show that the Standardized Root Mean Square Residual (SRMR) value is 0.078, which indicates that the model is acceptable as a good fit. Meanwhile, the model has an NFI value of 0.665, meaning that it is 66.5% fit (Table 11).

Hypotheses were tested using SEM via SmartPLS as presented in Fig 1. Based on this analysis, all SDG forestry values have a significant relationship, with a low to moderate degree of influence. This indicates that Perhutani needs improvements to a moderate to high influence a portion of the achievement of forestry-related SDGs in decision-making for Perum Perhutani's cajuput oil business management.Perum Perhutani has implemented a balanced approach between economic and environmental values in the production of cajuput oil, but it still requires improvement. According to the impact tests, Perum Perhutani has incorporated sustainable economic value into its cajuput oil business management, including improving community income, increasing Perum Perhutani's revenue, creating jobs, opening new economic opportunities, and expanding market access.

Furthermore, Perhutani has also paid attention to sustainable environmental values, such as soil fertility, disaster prevention, climate-responsive communities, and community participation in forest conservation. These aspects of value are incorporated into the management of Perum Perhutani's cajuput oil business, which currently involves planting, pruning, production, and sales activities. Forest village communities involved in Perum Perhutani's cajuput oil business benefit from the use of agroforestry land while cultivating

Table 10. R-*Square*

	R-square		R-square
Key Activities (Y7)	0.326	Value Proportion (Y2)	0.553
Revenue Streams (Y5)	0.393	Channels (Y3)	0.558
Customer Relationships (Y4)	0.349	Customer Segments (Y1)	0.355
Key Partnerships (Y8)	0.332	Cost Structure (Y9)	0.459
Key Resources (Y6)	0.354		

Table 11. Model Fit

	Saturated model	Estimated model
SRMR	0.078	0.138
NFI	0.665	0.585

cajuput plants. Some of the agroforestry crops grown alongside cajuput include corn (*Zea mays*), cassava (*Manihot esculenta*), rice (*Oryza sativa*), and various types of spices. Agroforestry development has promising prospects for contributing to increased farmer incomes around the forest as a livelihood, ensuring food security, providing firewood, and supporting sustainable agriculture (Maguire et al., 2013). However, the extent to which agroforestry is beneficial to Perum Perhutani requires further research to create greater economic benefits for forest village communities. Additionally, forest village communities receive wages for collecting cajuput leaves, which are processed into cajuput oil through distillation. These communities earn daily wages ranging from IDR 50,000 to IDR 100,000, either for harvesting or processing cajuput leaves. Structural Equation Model of SDGs Business Model of Perum Perhutani Cajuput Oil can preview in Figure 1.

Cajuput planting can improve the welfare of forest communities and create jobs in marginal areas adjacent to them, making it a beneficial option for reducing poverty and creating employment (Ernawati et al., 2021). Furthermore, Perhutani plays a role in assisting communities, providing outreach, acting as a discussion partner, offering training, and solving problems that communities cannot resolve on their own. Coordinating the role of cajuput oil producers with the local community and

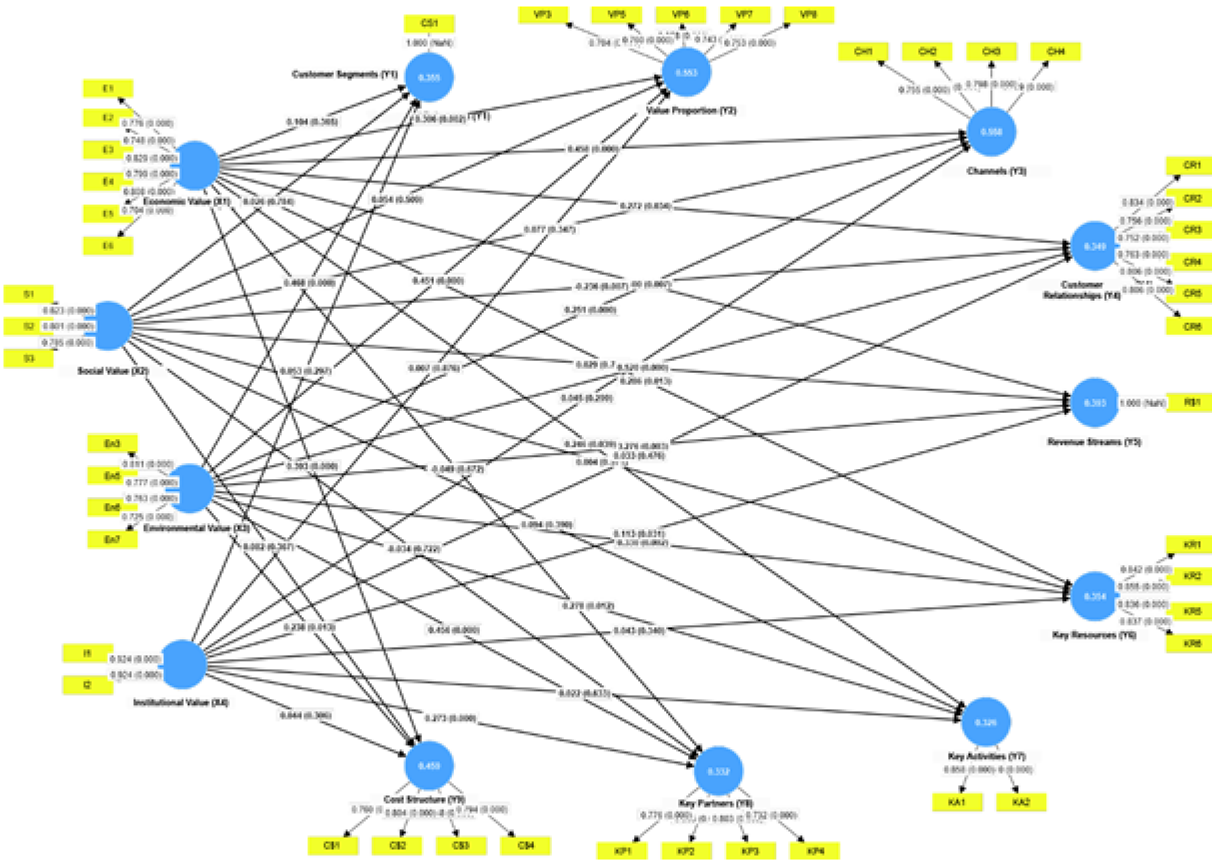

Figure 1. Structural Equation Model of SDGs Business Model of Perum Perhutani Cajuput Oil

environment in terms of adaptation, disaster mitigation, and land restoration is one of the strategies for enhancing the capacity of cajuput oil producers (Ernawati et al., 2021). As a result, more people will believe that purchasing cajuput oil products also contributes to improving social, economic, and environmental sustainability in Indonesia. These developments will foster the mindset that buying cajuput oil products means supporting environmental, economic, and social sustainability. To align with the concept of environmental sustainability, a paradigm shift in company behavior and human resources is necessary (Alikodra, 2020). Meanwhile, if Indonesia continue to import eucalyptus produced by other countries, then those who get added economic, social and environmental value are eucalyptus exporting countries. Based on the above analysis, Perum Perhutani's management of the cajuput oil business still faces many challenges, particularly in ensuring the economic sustainability of the cajuput oil business and increasing competitiveness to become more competitive

C. Competitiveness Study of Perum Perhutani's Cajuput Oil in Supporting Sustainability (SDGs) in the Forestry Sector

The resources and capabilities of Perum Perhutani's cajuput oil business, analyzed using RBV and VRIO theories, demonstrate several competitive resources compared to other domestic companies in Indonesia. The competitive resources of Perum Perhutani's cajuput oil business include tangible, intangible, and capabilities (Table 5). Furthermore, based on the structural test, economic and environmental values have a significant influence on the key resources of Perum Perhutani's management of the cajuput oil business (Table 7).

In terms of physical resources, Perum Perhutani's cajuput oil production relies on raw material facilities and factories. Perum Perhutani's cajuput plantations cover approximately 32,000 hectares, with around 39.6 million cajuput trees spread across 27 Forest Management Units.Perum Perhutani's cajuput oil factories made 29,142 tons of dried cajuput leaves in 2022. The average yield was 0.61%, which means they made about 182.8 tons of cajuput oil. Perum Perhutani has adequate and complete facilities and infrastructure for running the cajuput oil business. The storage of raw materials is aligned with the factory's processing capacity to prevent the quality degradation of cajuput leaves. On average, annual cajuput oil production is approximately 200–390 tons. Overall, the factory's production capacity meets the cajuput leaves supply. The total installed factory capacity at Perum Perhutani is 48,300 tons, and for example the real production used in 2022 is 29,142 tons so that only 60% of the capacity is produced.

Perum Perhutani's cajuput oil has relatively stable prices and better and more stable 1,8-Cineole content compared to the cajuput oil produced by the Forestry Office of Yogyakarta and cajuput oil from Buru Island (Table 8). While Perum Perhutani's cajuput oil is competitive in the domestic market, it requires attention for its development in the international market. The presence of imported eucalyptus oil is a factor that should be considered as a competitor to Perum Perhutani's cajuput oil resources. Imported eucalyptus has advantages in terms of price and 1,8-Cineole content. Perum Perhutani's cajuput oil is priced more than 1.5 times higher than imported eucalyptus oil and has lower 1,8-Cineole content, which results in weaker competitiveness in the international market compared to eucalyptus from China and Australia. The Import BM tax value for eucalyptus is 5%. This tax is imposed to protect domestic industries and provide incentives for domestic business. The BM Raw Material and Capital Goods Tax Rate ranges from 0% to 7.5%. The difference in value of eucalyptus imports with Perum Perhutani's eucalyptus oil is IDR 122,500/kg or $ 7.87 per kg. Recently, the influx of imported eucalyptus oil in the market has increased. If Perum Perhutani does not make efforts to develop its competitiveness against imported eucalyptus, it may face sustained losses. The behavior of Perum Perhutani's cajuput oil industry is still product-driven rather than market-driven. According to Hendrawan (2022), a market-driven strategy that a company can implement includes market orientation, differentiating characteristics, customer value, and superior performance. Among these strategies, customer value is crucial for Perum Perhutani's cajuput oil, particularly in terms of product price and quality, where Perum Perhutani's cajuput oil is not yet superior in international competition. Table. 12 illustrates the advantages of imported eucalyptus over Perum Perhutani's cajuput oil.

In terms of competitiveness, according to Porter (2011), companies achieve competitive advantage through either cost leadership, differentiation, or focus strategies. Cost leadership involves becoming the lowest-cost producer in the industry, while differentiation entails offering unique products or services that are valued by customers. These strategies enable firms to outperform competitors and achieve superior profitability. In addition to cost leadership and differentiation, the focus strategy emphasizes targeting a specific market segment or niche, which allows businesses to tailor their offerings and gain a competitive edge in that specific segment (Porter, 2011).

Perum Perhutani's cajuput oil demonstrates competitiveness in the domestic market, with prices set below the domestic market average and maintaining high cineole content, ensuring product quality. However, the global market presents significant challenges, as eucalyptus producers often operate as low-cost manufacturers that produce high-quality products with the added value that consumers seek. In this context, a focus strategy can complement Perhutani's existing efforts by concentrating on specific market segments, such as organic or sustainable product consumers, who prioritize environmental and social responsibility in Indonesia, eucalyptus imports are produced by other countries, thus benefiting the exporting country economically, socially, and environmentally. Business system innovation should use both qualitative and quantitative approaches (Kajanus et al., 2019)

By leveraging its focus on sustainability, Perhutani's cajuput oil contributes to broader societal sustainability and taps into niche markets where consumers are increasingly conscious of the environmental and social impacts of the products they purchase. This focus on ethical production can set Perhutani apart from global competitors who may prioritize cost leadership. Furthermore, Perhutani has expanded its focus by developing derivative products from cajuput oil, such as telon oil, medicines, and cosmetics, which cater to specific customer needs in pharmaceuticals and the wellness sector. Such a focused approach enables Perhutani to maintain relevance in competitive niches that are not solely driven by cost but by the value-added qualities of the product (Batubara et al., 2016).

Table 12. Comparison of Perum Perhutani's Cajuput Oil with Market Competitors.

	Cajuput oil Perum Perhutani	**Forestry Office of Yogyakarta**	**Buru Island**	**Eucalyptus impor**
Price (IDR/kg)	295.000	290.000 – 300.000	288.000 – 355.000	130.000 – 225.000
1,8-Cineole (%)	57 – 65	53 – 56	24 – 64	77 – 81
Yield (%)	0,6 – 0,8	0,7 – 0,8	0,6 – 0,8	1,5 – 2,0

Source: RnD of NTFP Commercial Division of Perum Perhutani, (2023); Torry & Idrus, (2016); Center for Facilitation of Implementation of Standardized Instruments of the Environment and Forestry, (2023).

IV. CONCLUSION

The key resources of Perum Perhutani's cajuput oil business that provide a sustainable competitive advantage are the quality of Perum Perhutani's cajuput oil seedlings, the ability to achieve supply chain certification, and the ability to produce high-quality products. The factors that significantly influence Perhutani's cajuput oil business are economic and environmental values, indicating that the management of the cajuput oil business has considered all indicators of tangible and intangible resources, capabilities, and assets. Cajuput oil from Perhutani has excellent competitiveness, especially in the domestic market, but it has been undermined by cheap imported eucalyptus oil. If this trend continues, consumer preferences may shift toward eucalyptus oil, even though the development of the MKP (cajuput oil) industry is actually more cost-effective, socially responsible, and environmentally friendly. This study has limitations that only generally relate SDGs to the Perhutani Cajuput oil business, so the suggestion for further research is to look for relationships with indicators that are not comprehensive in this study or to focus more on one indicator that is more in-depth, whether social, ecological, or economic.

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VEGETATION AND SOIL BIODIVERSITY ASSESSMENT IN TEMPERATE FORESTS SURROUNDING THE KHAZAR NABI MARSHES, IRAN

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VEGETATION AND SOIL BIODIVERSITY ASSESSMENT IN TEMPERATE FORESTS SURROUNDING THE KHAZAR NABI MARSHES, IRAN. A thorough understanding of biodiversity is crucial for the sustainable management and conservation of forest ecosystems. This study investigates vegetation cover in conjunction with key environmental factors—including physiographic features, soil characteristics, and climatic conditions—in the Nimvar Forest of Nowshahr, Iran. Vegetation zoning was conducted in areas surrounding the Khazar Nabi Marshes based on the degree of homogeneity and heterogeneity among vegetation units. The primary objective of this research is to evaluate vegetation and soil biodiversity within the temperate forests adjacent to the marshes. Plant diversity was quantified using the Simpson and Shannon-Wiener indices, while species richness was assessed through the Margalef and Menhinick indices. The Berger-Parker and Pielou's indices were also employed to evaluate species dominance and evenness. Results indicated that both species diversity and richness reached their highest levels in the eastern, northern, and northeastern parts of the study area. Statistically significant differences in species richness and evenness ($p < 0.05$) were observed among these regions. The predominant soil texture in areas surrounding the marsh was sandy clay loam (62.5%). Notable variation was found in clay content ($p < 0.01$), organic matter ($p < 0.01$), and soil pH ($p < 0.05$). Beech species were most abundant on the northern slopes, whereas the Gramineae family represented the most dominant plant group overall. These findings emphasize the marsh's role in shaping local vegetation patterns and soil attributes, contributing to the development of a distinct microhabitat with unique microclimatic conditions.

Keywords: Biodiversity, Forest trees, Fagus *orientalis*, Hyrcanian forest

PENILAIAN KEANEKARAGAMAN HAYATI VEGETASI DAN TANAH DI HUTAN BERIKLIM SEDANG DI SEKITAR RAWA-RAWA KHAZAR NABI, IRAN. Pemahaman menyeluruh tentang keanekaragaman hayati sangat penting untuk pengelolaan dan konservasi ekosistem hutan yang berkelanjutan. Studi ini meneliti tutupan vegetasi beserta faktor lingkungan utama—termasuk fitur fisiografi, karakteristik tanah, dan kondisi iklim—di Hutan Nimvar Nowshahr, Iran. Zonasi vegetasi dilakukan di area sekitar Rawa Khazar Nabi, berdasarkan tingkat homogenitas dan heterogenitas di antara unit vegetasi. Tujuan utama penelitian ini adalah untuk mengevaluasi keanekaragaman hayati vegetasi dan tanah di dalam hutan beriklim sedang yang berdekatan dengan rawa-rawa. Keanekaragaman tumbuhan diukur menggunakan indeks Simpson dan Shannon-Wiener, sedangkan kekayaan spesies dinilai melalui indeks Margalef dan Menhinick. Indeks Berger-Parker dan Pielou juga digunakan untuk mengevaluasi dominasi dan kemerataan spesies. Hasil penelitian menunjukkan bahwa keanekaragaman dan kekayaan spesies mencapai tingkat tertinggi di bagian timur, utara, dan timur laut dari area penelitian. Perbedaan yang signifikan secara statistik dalam kekayaan dan kemerataan spesies ($p < 0,05$) diamati di antara wilayah-wilayah ini. Tekstur tanah yang dominan di area sekitar rawa adalah lempung berpasir (62,5%). Variasi yang signifikan ditemukan pada kandungan lempung ($p < 0,01$), bahan organik ($p < 0,01$), dan pH tanah ($p < 0,05$). Spesies beech paling banyak ditemukan di lereng utara, sedangkan

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famili Gramineae merupakan kelompok tanaman yang paling dominan secara keseluruhan. Temuan ini menekankan peran rawa dalam membentuk pola vegetasi lokal dan atribut tanah, yang berkontribusi pada pengembangan mikrohabitat yang berbeda dengan kondisi iklim mikro yang unik.

Kata kunci: Keanekaragaman hayati, Pohon hutan, Fagus orientalis, Hutan Hyrcanian

I. INTRODUCTION

The northern forests of Iran, known as the Hyrcanian forests, are among the most ecologically significant temperate forests in the world, harboring a rich diversity of valuable tree species. These include *Fagus orientalis* Lipsky (oriental beech), *Quercus castaneifolia* C.A. Mey. (chestnut-leaved oak), *Carpinus betulus* L. (european hornbeam), *Parrotia persica* C.A.M. (ironwood), *Pterocarya fraxinifolia* Land. (false walnut), *Populus caspica* Bornm. (caspian poplar), *Alnus subcordata* C.A. Mey. (caucasian alder), *Buxus hyrcana* Pojark (box tree), *Gleditschia caspica* Desf. (caspian honey locust), *Acer velutinum* Boiss. (velvet maple), and *Sorbus torminalis* (L.) Crantz. (wild service) (Marvie Mohadjer, 2011; Aghajani et al., 2014, 2019). Biodiversity encompasses the variability among living organisms from all sources—terrestrial, marine, and freshwater ecosystems—along with the ecological complexes they form. It is commonly described across three levels: genetic diversity, species diversity, and ecosystem diversity. As such, biodiversity represents the full spectrum of life's variety, complexity, and interactions (Ejtehadi et al., 2009). The conservation of forest ecosystems and the protection of their unique species are vital for maintaining genetic reservoirs and ensuring ecological stability. Sustainable forest management practices, are essential for health and preserving these ecosystems over the long term (Aghajani et al., 2013). Environmental factors, such as humidity and temperature, play a pivotal role in shaping biodiversity, particularly fungal communities (Bari et al., 2021; Aghajani et al., 2018). Forest and marsh ecosystems are recognized as biodiversity hotspots that support a wide range of plant, fungal, animal, and microbial life. Marshes are defined as wetlands characterized by dominant herbaceous vegetation in inland settings (Wang et al., 2023). Forests, in contrast, are dynamic ecosystems constantly influenced by both natural processes and human interventions. Any disruption to marshes—whether through direct degradation or indirect impact—can profoundly disturb ecological cycles (Mahmoodi et al., 2019). Macrofauna are reliable indicators of habitat productivity and serve as valuable tools in evaluating sustainable forest management practices. Ghorbanzadeh et al. (2018) investigated the impact of various afforestation approaches on soil fauna, biodiversity metrics, and their relationship with key soil physical and chemical properties. Their findings revealed that microbial respiration, microbial biomass carbon and nitrogen, and bacterial populations were highest in poplar plantations, followed by natural forest sites. Vegetation, as one of the most dominant and observable forms of life on Earth, is deeply intertwined with human life and culture. As Miller (1978) observed, vegetation is not merely a natural element but a foundational component of human existence. Studying vegetation alongside physiographic, edaphic, and climatic factors enables a better understanding of the stability of plant communities and the ecological dynamics that govern them—an essential prerequisite for the restoration and sustainable development of forest ecosystems.

The importance of biodiversity management, particularly in the context of conservation and the sustainable use of ecological resources, remains a foundational goal in natural resource policy (Es-hagh Nimvari et al., 2011). Numerous studies have explored the biodiversity of woody species. For instance, Mao et al. (2020) emphasized the irreplaceable ecological role of wetlands as some of the world's most productive ecosystems. Mahmoodi et al. (2019) analyzed vegetation diversity along a catena in managed and unmanaged stands of the Asalem forest, concluding that slope position significantly influenced the Simpson index and Camargo's evenness for trees, as well as Simpson and Margalef indices for herbaceous species. HajMirzaAghaei et al. (2021) examined the impact of native broadleaf and exotic conifer plantations on understory diversity in northern Iran, revealing that monoculture plantations led to reduced biodiversity, whereas mixed stands supported greater species richness. Similarly, Mosavi et al. (2022) demonstrated that physiographic variables such as slope aspect and elevation significantly affect biodiversity and aboveground biomass, with beech forests on mid-elevation northern slopes showing the highest biomass. Kianmehr et al. (2022) compared herbaceous diversity and regeneration in pure and mixed stands of beech and hornbeam. Their findings confirmed the practicality of biodiversity indices in forest assessments due to their reliability, cost-effectiveness, and adaptability. The study predicted a future dominance of oriental beech in the regeneration composition. Other research has underscored the value of structural indices, analyzed using advanced tools like machine learning and airborne laser scanning. Ette et al. (2023) investigated the correlation between different biodiversity indices, while Ette and Geburek (2021) addressed concerns regarding the reliability of biodiversity reporting in Europe. The UNECE-FAO (2020) report and Heym et al. (2020) highlighted the essential role of forest inventory data in biodiversity monitoring and sustainable forest governance. Ataei et al. (2023) assessed plant diversity along an elevational gradient in the Hyrcanian forests and found that species richness peaked between 800 and 1,300 meters above sea level, based on Shannon-Wiener and Simpson indices. Alijanpour et al. (2009) investigated woody species diversity in protected versus unprotected zones of the Arasbaran forest and found that conservation measures significantly enhanced biodiversity. In the Kalardasht region of Mazandaran, Razaghi Kamroodi and Akbarzadeh (2002) identified 21 woody species and nine tree species, noting a temporal increase in species richness. Kazemnezhad et al. (2009) compared biodiversity in managed and unmanaged hornbeam-beech stands in the Laroochal region of Nowshahr. The average species richness index for trees was 3.37 in unmanaged areas and 2.43 in managed sites; tree evenness averaged 0.71 and 0.78, respectively. The Shannon-Wiener index was 0.79 in unmanaged and 0.57 in managed stands, while the Simpson index was 0.43 and 0.34, respectively. Neumann and Starlinger (2001) evaluated the effectiveness of various diversity metrics and concluded that the Shannon-Wiener index remains one of the most suitable for assessing tree species diversity.

Due to its floristic uniqueness and ecological richness, the Nowshahr forest region was selected as the study area, representing one of the key biodiversity reservoirs in Iran. This research aims to assess biodiversity status in the region, with the understanding that detailed knowledge of species composition and distribution is critical for sustainable forest management. Considering the ecological value of the Hyrcanian forests as biodiversity hotspots and refuges for native ecosystems, there is a pressing need to employ effective biodiversity indicators. Accordingly, six widely accepted biodiversity indices were used in this study: Margalef and Menhinick indices (species richness), Shannon-Wiener and Simpson indices (species diversity), and Berger-Parker and Pielou's indices (dominance and evenness). Given the growing threats to forest ecosystems and the irreplaceable ecological role of northern Iran's forests within the national phytogeographic framework, this study offers a comprehensive evaluation of biodiversity that can inform conservation policies and guide the future management of similar ecosystems, including the forested marshes and ecotonal zones of the Hyrcanian region.

II. MATERIALS AND METHODS

A. General Conditions and Geographical Location

defined by national watershed classification systems, and represents the fourth delineated series within this watershed. Administratively, it falls under the jurisdiction of the Kheyroud Natural Resources Division and the Noor-Royan Natural Resources Administration. Ecologically and topographically, the Darno Series 4 is located within the mid-mountain zone, characterized by a broad elevational gradient. The elevation ranges from approximately 400 meters above sea level in compartment 401 to about 1,800 meters in the upper administrative zone 430 (see Figure 1).

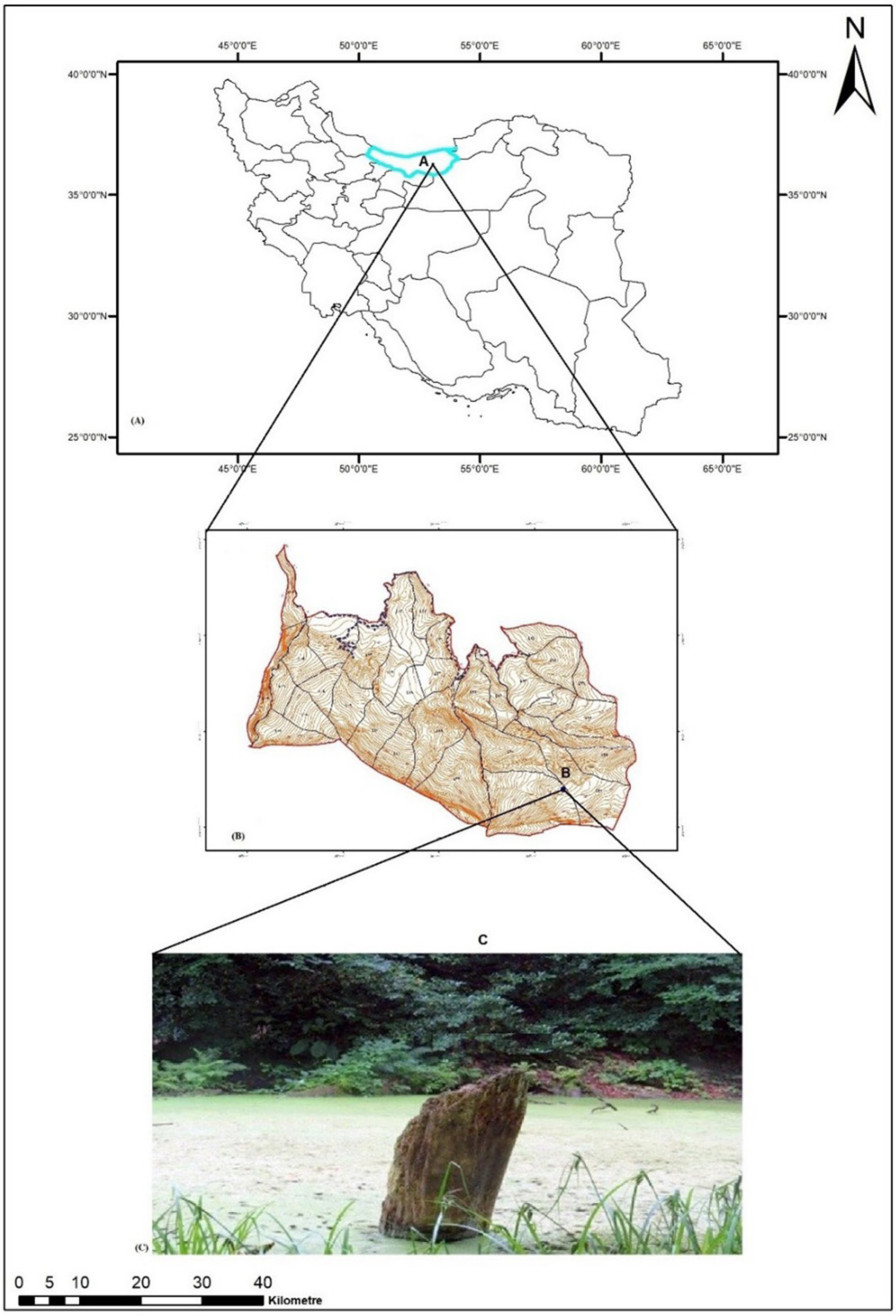

Figure 1. A: Map of Iran B: map of administrative area C: Study area in Khezre-Nabi marshes in northern Iran

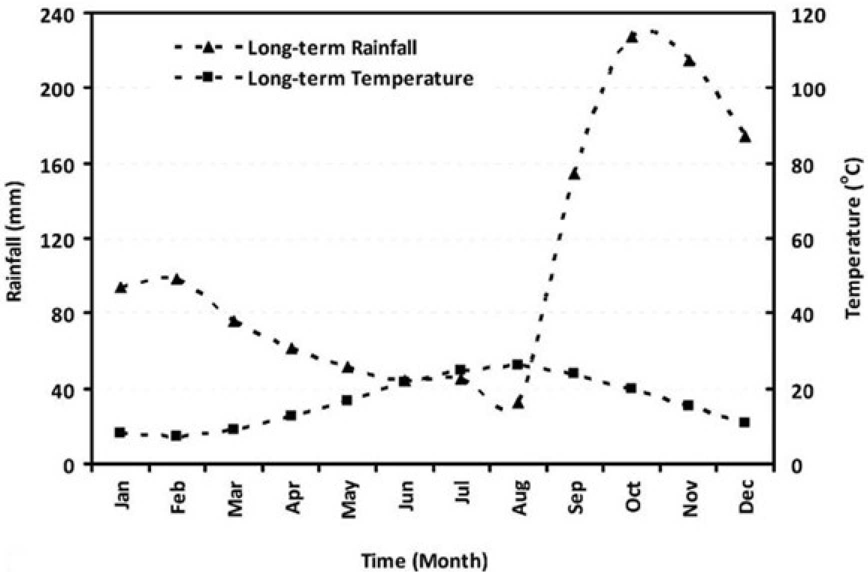

Figure 2. Ombrothermic curve of Nowshahr Synoptic Station in 1991 to 2011

B. Ombrothermic Curve

Based on a 20-year dataset (1991–2011) from the Nowshahr synoptic station, the study area receives an average annual precipitation of 1,273 mm and has a mean annual temperature of 19.6°C. The region's climate is classified as semi-humid, characterized by cold winters. October is the wettest month, with an average precipitation of 227.4 mm, while August is the driest, receiving only 32.1 mm of rainfall. The ombrothermic diagram for the area (Figure 2) illustrates the seasonal precipitation-temperature relationship and indicates approximately 40 dry days annually (Aghajani et al., 2016).

C. Methodology

A preliminary reconnaissance survey was conducted in the study area, and the site was mapped using GPS. Based on the homogeneity and heterogeneity of vegetation units relative to their distance from the marshes, the area was stratified into three distinct sampling zones. Zone I, adjacent to the marshes, represents shoreline vegetation; Zone III, the farthest, corresponds to the surrounding forest; and Zone II lies between these two extremes. A total of sixty plots, each measuring 1 × 2 meters, were established along eight geographical transects. Plant species that could not be identified in the field were collected and later identified to the species level using standard taxonomic references. Within each plot, data were recorded on species composition and abundance, canopy and trunk health, diameter at breast height (DBH), and total tree height. Additionally, soil samples were collected from the forest edge near the marshes and analyzed in the laboratory for texture, organic matter content, pH, salinity, and moisture. The data were subjected to one-way analysis of variance (ANOVA), followed by Duncan's multiple range test to assess differences among indices and evaluate spatial variability within the study area. The findings were further contextualized through comparison with relevant literature.

1) Biodiversity Indices Analysis

The following biodiversity indices were calculated based on Ludwig & Reynolds (1988) and Hammer et al., (2001)

2) S impson's Diversity Index:

Simpson's Diversity Index is one of the earliest diversity indices used in ecology. The index ranges from 0 to 1; a higher value indicates a greater probability that two individuals randomly selected from a sample belong to the same species, implying lower diversity. It was introduced by Ludwig & Reynolds (1988) and is defined according to Formula 1:

(1):
$$\lambda = 1 - \sum_{i=1}^{0} \left[\frac{ni\,(ni-1)}{N\,(N-1)} \right]$$

Where:
ni: number of individuals of each species
N: total number of individuals in the community
λ: Simpson's diversity index

3) Shannon–Wiener Diversity Index:

The Shannon–Wiener index is more sensitive to the presence of rare species. The Shannon–Wiener equation uses the natural logarithm and is expressed as follows:

(2):
$$H' = -\sum_{i=1}^{s} p_i \ln(p_i)$$
$$p_i = \frac{n_i}{N}$$

Where:

H : Shannon–Wiener Diversity Index:

Pi: Relative abundance of individuals of species *i* in the sample

ni: Number of individuals of species

N: Total number of individuals in the community

4) Species Richness Indices

Species richness, also referred to as species density, refers to the total number of species present. The main mathematical indices used to quantify species richness include:

5) Margalef's Richness Index

This index uses the following formula (Equation 3) to calculate species richness:

(3):
$$R = \frac{S-1}{LnN}$$

Where:

R = Species richness (Margalef's index)

S = Total number of species

N = Total number of individuals in the community

6) Menhinick's Species Richness Index.

This index is calculated using the Formula (4):

(4):
$$R = \frac{S}{\sqrt{N}}$$

Where:

R = Species richness

S = Total number of species

N = Total number of individuals in the community

7) Species Evenness Index

To calculate species evenness, several indices are used. The most important ones are as follows:

8) Pielou's Evenness Index

The Pielou's evenness index is calculated using the following formula (5):

Where:

(5):
$$j' = \frac{H'}{H'_{max}}$$

H' : Shannon–Wiener Index:

j' : The Pielou's Evenness value

H'_{max} : The maximum possible value of the Shannon-Wiener index is equal to: Lns=-H'_{max}

9) Dominance – Berger-Parker Index

The Berger-Parker dominance index is one of the most commonly used dominance indices. It provides a straightforward understanding of the concept of dominance within a community and is easy to calculate. The Berger-Parker index is based on the most dominant species and is calculated using the following formula (6):

(6):
$$D_d = \frac{N_{max}}{N}$$

Where:

Dd = Berger-Parker dominance

Nmax = Dominant species abundance

N = Total number of individuals in the community

10) Statistical Analysis

Duncan's multiple range test (DMRT) was employed to compare the means of quantitative characteristics, while analysis of variance (ANOVA) was utilized. Biodiversity indices for the Marshes were computed using PAST software (Hammer et al., 2001), whereas all statistical analyses were performed using SPSS software (Kahrizi et al., 2020).

III. RESULTS AND DISCUSSION

A. Biodiversity Indices in the Marshes and Geographic Directions

The analysis of biodiversity indices across the Marshes and geographic directions showed no significant differences at the 0.05 level for Simpson's diversity index (p = 0.812), Shannon-Wiener diversity index (p = 0.256), Margalef's richness index (p = 5.423), Menhinick's richness index (p = 1.3325), evenness (p = 0.312), and the Berger-Parker dominance index (p = 0.213) (Table 1).

B. ANOVA for Biodiversity Indices in the Marshes and Geographic Directions

Analysis of variance for biodiversity indices across the three marsh zones revealed no statistically significant differences at the 5% level for Simpson's diversity index (p = 0.652), Shannon-Wiener diversity index (p = 0.120), Menhinick's richness index (p = 0.374), or the Berger-Parker dominance index (p = 0.556). However, Margalef's richness index (p = 0.018) and Pielou's evenness index (p = 0.021) showed significant differences. Similarly, across different geographic orientations, no significant differences were observed for Simpson's index (p = 0.282), Shannon-Wiener index (p = 0.254), Menhinick's index (p = 0.550), or the Berger-Parker index (p = 0.221). In contrast, Margalef's richness index (p = 0.012) and evenness (p = 0.017) exhibited statistically significant variation at the 5% significance level (Table 2).

Species richness refers to the total number of species present within a given sample plot, with higher species counts indicating greater ecological richness. In contrast, evenness describes the relative distribution of individuals among different species within a community. Communities dominated by one or two species demonstrate lower diversity than those with a more balanced species composition. Both high species richness and high evenness contribute to greater overall biodiversity in a region. In the present study area, which is characterized by the dominance of three major tree species, species richness was found to be relatively adequate (Ejtehadi et al., 2009).

The calculated Shannon-Wiener and Simpson diversity indices for the study area

Table 1. Values for biodiversity indicators between marshes and geographical directions

Dominance of Berger-Parker	Evenness of Pielou's	Richness of Manhanic	Richness of Margalef	Shannon Weiner Variety	Simpsons Variety	Geoghrapical direction
0.2314	0.3564	1.669	4.562	2.331	0.7523	North
0.1456	0.4521	2.3287	5.2598	2.233	0.8365	Northeast
0.1468	0.5419	1.6520	5.2135	2.4523	0.9254	Eastern
0.2014	0.6621	2.214	4.5637	1.3675	0.5602	Southeast
0.6210	0.2397	1.6579	2.4412	2.0345	0.2112	South
0.6376	0.6341	1.375	4.0397	2.752	0.973	Southwest
0.6321	0.5520	1.8820	5.3674	1.8932	0.6482	West
0.331	0.6541	1.9971	3.8531	2.8823	0.2236	Northwest
0.2136	0.3125	1.3325	5.4236	2.256	0.8124	Marsh

Table 2. Finding of two-way ANOVA (A marshes and B geographical direction) for biodiversity indicators

P	F	Mean Squares	df	Unit element (orientation relative to marsh)	Biodiversity index
0.652ns	0.225	0.001	2	Marsh	Simpsons Variety
0.282ns	1.325	0.002	7	direction	
0.120ns	2.221	0.186	2	Marsh	Shannon Weiner Variety
0.254ns	1.114	0.183	7	direction	
0.018 *	1.154	6.365	2	Marsh	Richness of Margalef
0.012 *	1.654	3.562	7	direction	
0.374ns	1.325	0.44	2	Marsh	Richness of Manhanic
0.550 ns	0.85	0.235	7	direction	
0.021*	2.730	0.033	2	Marsh	Evenness of Pielou's
0.017*	2.360	0.021	7	direction	
0.556 ns	0.125	0.001	2	Marsh	Dominance of Burger parker
0.221 ns	2.154	0.005	7	direction	

suggest a comparatively high level of species diversity relative to other regions. For instance, Amini and Pourbabaei (2004) reported average Shannon-Wiener index values of 2.22 for Norway maple (*Acer platanoides*) forests and 2.17 for pristine forests in Gilan Province. Similarly, Kazemi et al. (2015) found average Simpson and Shannon-Wiener index values of 0.63 and 1.16, respectively, in the Khalil Mahalleh forests of Mazandaran Province. Numerous studies have emphasized the suitability of the Shannon-Wiener index for evaluating tree species diversity (Bahmani et al., 2014). Mohammadzadeh et al. (2015) further highlighted that evenness plays a critical role in enhancing Simpson's index, while species richness has a greater influence on the Shannon-Wiener index. Their findings from the Arasbaran forest, a natural broadleaf deciduous ecosystem with high biodiversity, are consistent with the results of the present study. Additionally, Chao (1999) underscored the role of marshes in moderating microclimatic conditions during colder seasons, which in turn promotes increased plant and animal diversity in surrounding areas.

The spatial distribution of flora, as assessed through various diversity indices, revealed no significant differences at the 5% level. Notably, the southern aspect of the Khazr Nabi Marshes exhibited the highest species evenness. Although diversity and dominance indices showed no statistically significant variation across geographic directions, the greatest species richness and evenness were observed on the southern and southeastern slopes. This pattern may be attributed to the elevated positions of these slopes, which receive optimal sunlight—an observation consistent with the findings of Adamus et al. (1991). However, significant directional differences were identified in species diversity, richness, and dominance indices. Specifically, the southwestern and western slopes exhibited the highest species richness and diversity, whereas the southern slope was dominated by a few species, indicating lower evenness. These trends correspond with the findings reported by Grigal (2002).

Further analysis of species abundance and richness across geographic directions revealed that the greatest abundance occurred on the northwestern slope, while the northeastern slope exhibited the highest species richness. These observations are in agreement with those of Kiesecker et al. (2001). An interaction analysis between geographic direction and biodiversity indices in the Khazr Nabi Marshes demonstrated that only Margalef's richness index and evenness were significantly affected, whereas other biodiversity indices remained unaffected.

C. Species Abundance in the Study Area

The findings revealed that *Fagus orientalis* Lipsky (oriental beech) exhibited the highest abundance among the recorded tree species, whereas *Carpinus betulus* L. (European hornbeam) and *Tilia platyphyllos* Scop. (large-leaved lime) had the lowest abundance (Figure 3). The study area, situated within a protected zone dominated by mixed oriental beech forests, underscores the ecological and commercial importance of *Fagus orientalis*. The predominance of this species suggests that the habitat conditions in the region—particularly those influenced by the nearby Marshes—are highly favorable for its growth and regeneration. The Marshes likely contribute to stable moisture regimes and a moderated microclimate, creating optimal conditions for oriental beech, a finding consistent with the observations of Mitsch and Gosselink (2000).

D. Seedlings Abundance in the Study Area

The analysis indicated that seedling abundance was highest among maple species, while beech seedlings exhibited the lowest abundance in the study area (Figure 4). The Khazr Nabi Marshes, situated at an elevation of 1,400 m above sea level, are primarily characterized by beech forests. The dominant species in the region include *Alnus subcordata* (caucasian alder), *Acer velutinum Boiss*. (velvet maple), and scattered individuals of *Carpinus betulus* L. (European hornbeam) and *Tilia platyphyllos* Scop. (large-leaved lime). The notable presence of *Alnus subcordata* in proximity to the Marshes is likely attributable to its affinity for moisture-rich habitats. Similarly, the prevalence of softwood species such as Acer velutinum may be explained by the lightweight nature of their seeds, which facilitates wider dispersal across the landscape. These observations are consistent with the findings of Kazemi et al. (2015), who reported that the occurrence of pioneer species such as *Alnus* and *Acer* in beech-alder and beech–maple forest types contributes to a reduction in beech dominance, thereby promoting greater tree species diversity.

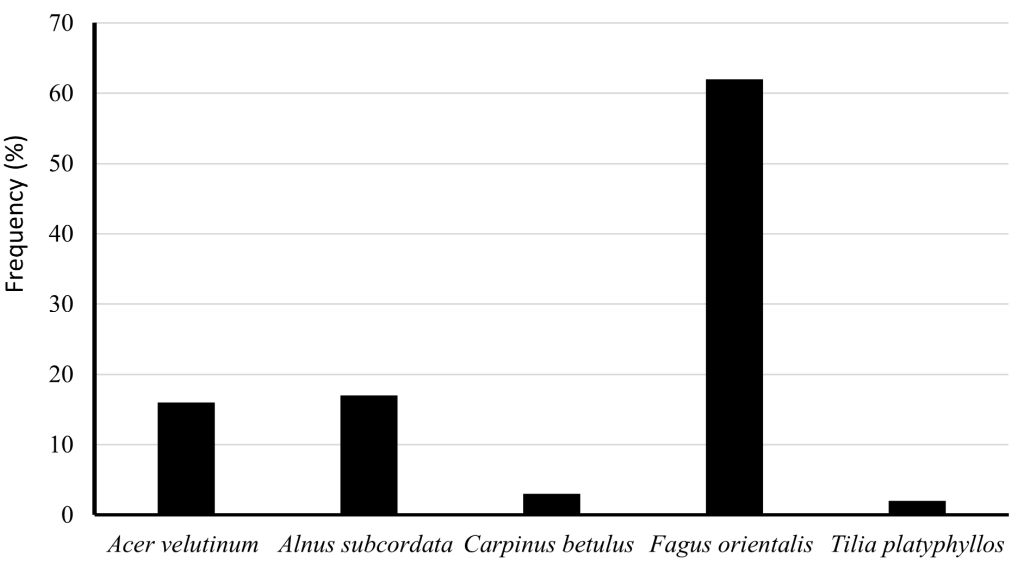

Figure 3. Species frequency in the study area

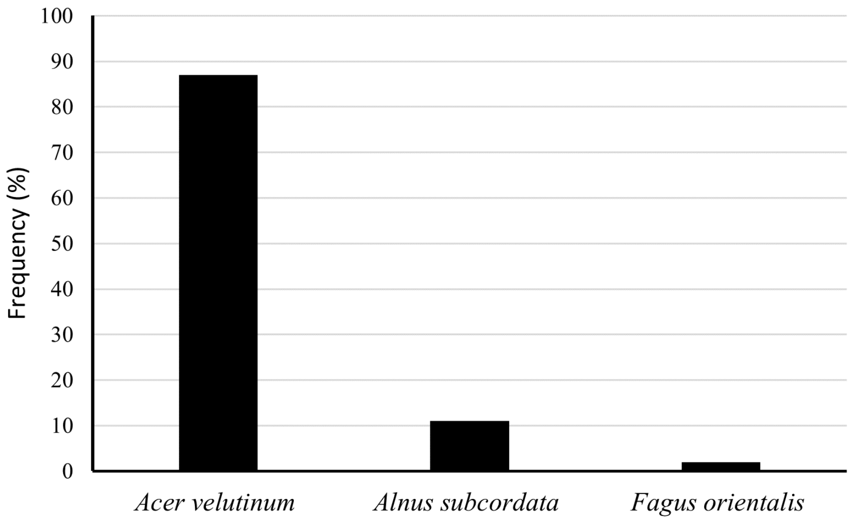

Figure 4. Regeneration species frequency in the study area

E. Crown and Stem Health Results in the Study Area

The results showed that the highest proportion of trees with healthy crowns was *Fagus orientalis* (oriental beech) trees (Figure 5).

A comparative analysis of average crown health in relation to tree height revealed that trees in the study area, which are predominantly young, exhibit generally good crown and stem vitality. In particular, the trees within the Khazr Nabi Marshes display excellent overall condition, a pattern likely attributable to the favorable microclimatic conditions and the site's classification as a climax forest. Statistical analysis demonstrated a highly significant relationship between crown health and tree height at the 99% confidence level. Similarly, a comparison between average stem health and diameter at breast height (DBH) showed that the greatest frequency of healthy trees occurred within the DBH range of 20–55 cm, predominantly representing young to middle-aged *Fagus orientalis* (oriental beech) individuals. The analysis of variance also indicated a highly significant difference between stem health and DBH at the 99% confidence level.

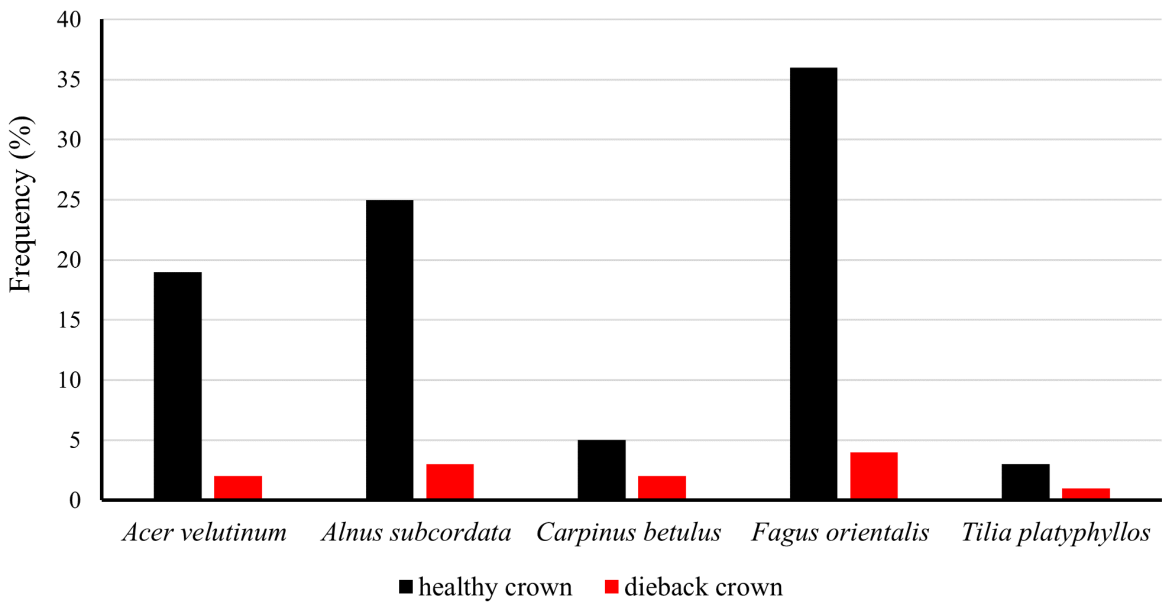

Figure 5. Crown health in the study area

In general, marsh ecosystems tend to exhibit lower environmental variability than adjacent terrestrial ecosystems due to the moderating influence of water. This hydrological buffering effect supports the persistence of marsh-adapted plant species, many of which have widespread global distributions and are commonly found in similar wetland environments.

F. Soil Characteristics of the Study Area

Soil texture analysis showed that the Khazr Nabi Marshes has a loamy sand soil texture. The soil texture comprises loamy clay sand (62.5%), loamy sand (25%), and loam (12.5%). Analysis of variance for soil factors revealed significant differences at the 1% level for clay content (P=0.001) and organic matter (P=0.002). Additionally, soil pH showed a significant difference at the 5% level (P=0.016). However, no significant differences were observed for silt (P=0.283), sand (P=0.123), soil salinity (P=0.21), and soil moisture (P=0.301) (Table 3).

The observed significant differences in clay content and organic matter across the Marshes can be attributed to variations in underlying soil horizons and the decomposition of forest floor litter, which contributes to elevated organic matter levels relative to other Marshes, as reported by Adamus et al. (1991). These findings corroborate the results of Eshagh-Nimvari (2014), who documented that the Jamand Marshes exhibited the highest clay content among three studied Marshes, while no significant differences were found in sand percentage, soil salinity, or moisture levels. Notably, the highest soil pH was recorded in the Jamand Marshes. Soil texture classifications further distinguish these ecosystems: the Talur and Farakhin Marshes predominantly contain loamy sand soils, whereas the Jamand Marshes comprise loamy clay sand, loamy sand, and loam textures (Eshagh-Nimvari, 2014). The present study's results are consistent with those of Touarfia et al. (2021), who demonstrated strong interrelationships between soil properties and plant species composition in the Mekeiman Marshes, highlighting the critical role of soil-plant interactions in the effective restoration and management of Marsh ecosystems. Moreover, plant species distribution was found to be influenced by moisture gradients, with key edaphic factors—including sodium, phosphorus, active lime, magnesium, clay content, organic matter, carbon-to-nitrogen (C/N) ratio, and nitrogen levels—significantly shaping vegetation patterns. These findings underscore the importance of conserving natural habitats and prioritizing the protection of natural forest Marsh stands to ensure the long-term ecological sustainability of northern forest Marsh ecosystems.

Table 3. ANOVA results of some soil properties

P	F	df	Mean Squares	Soil Characteristics
0.001**	47.120	2	358.167	Clay
0.283 ns	1.341	2	69.292	Silt
0.123 ns	2.322	2	113.375	Sand
0.002**	8.434	2	1036.137	Organic matter
0.016*	5.033	2	2.044	pH
0.21 ns	1.683	2	0.063	EC
0.301 ns	1.271	2	173.375	Humidity

IV. CONCLUSION

The results demonstrate that the Marshes significantly influence vegetation composition and soil properties, thereby creating a unique microhabitat characterized by specific climatic conditions. Biodiversity indices proved to be essential tools for assessing and comparing species diversity across different forest regions, providing critical insights into the stability and overall health of forest ecosystems. These findings emphasize the crucial role of conserving and restoring natural habitats to sustain both plant and animal diversity. Moreover, the notable presence of species such as maple, with its high seedling abundance, and oriental beech, distinguished by its exceptional crown health, highlights the imperative for targeted conservation strategies aimed at protecting these keystone species and their associated ecosystems.

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MORPHOLOGICAL, ANATOMICAL, AND PHYSIOLOGICAL CHANGES DURING SEED MATURATION OF SUGAR PALM (*Arenga pinnata* Merr.)

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MORPHOLOGICAL, ANATOMICAL, AND PHYSIOLOGICAL CHANGES DURING SEED MATURATION OF SUGAR PALM (Arenga pinnata Merr.). *Arenga pinnata* (sugar palm) seeds are classified as seeds that have a long dormancy period. This dormancy can be influenced by the maturity level of the sugar palm fruit. This study aims to characterize the morphology and anatomy at various levels of fruit maturity and its relationship to the dormancy of sugar palm seeds. The research was conducted descriptively, involving data collection through morphological, anatomical, and physiological observations of sugar palm fruits and seeds randomly selected from productive sugar palms in Nagari Andaleh Baruh Bukik, Sungayang Subdistrict. The sampling technique was conducted through the purposive sampling method on 12 productive palm trees aged 10 years and above. The results showed that morphologically, there were changes in the color of the skin of the palm fruit to yellowish when it reached physiological maturity, as well as the texture of the hardened seed shell. Changes did not follow these changes in shell color and seed size. Physiologically, there is an increase in gibberellin hormone levels along with the increase in fruit maturity, and it continues to increase when entering the germination phase. Anatomically, the structure of the seed embryo does not show significant changes since the beginning of the fruit ripening. Based on this, there is a mutual relationship between the morphological and physiological characteristics of the dormancy of sugar palm seeds. The riper the palm fruit is, the harder the seed shell is, so the seed dormancy becomes longer and is known as morphophysiological dormancy.

Keywords: apocol, embryology, morphophysiology, ripening, sugar palm

PERUBAHAN MORFOLOGI, ANATOMI, DAN FISIOLOGI SELAMA PEMATANGAN BENIH AREN (Arenga pinnata Merr.). Benih aren tergolong benih yang memiliki masa dormansi yang panjang. Dormansi ini dapat dipengaruhi oleh tingkat kematangan buah. Penelitian ini bertujuan untuk mengkarakterisasi morfologi dan anatomi pada berbagai tingkat kematangan buah dan hubungannya dengan dormansi benih aren. Penelitian dilakukan secara deskriptif, yaitu pengumpulan data melalui pengamatan morfologi, anatomi, dan fisiologi buah dan benih aren yang dipilih secara acak dari pohon aren produktif di Nagari Andaleh Baruh Bukik, Kecamatan Sungayang. Teknik pengambilan sampel dilakukan dengan metode purposive sampling pada 12 pohon aren produktif yang berumur 10 tahun ke atas. Hasil penelitian menunjukkan bahwa secara morfologi terdapat perubahan warna kulit buah aren menjadi kekuningan saat mencapai kematangan fisiologis dan tekstur cangkang benih yang mengeras. Perubahan tersebut tidak diikuti oleh perubahan warna cangkang dan ukuran benih. Secara fisiologis, terjadi peningkatan kadar hormon giberelin seiring dengan bertambahnya kematangan buah dan terus meningkat saat memasuki fase perkecambahan. Secara anatomi, struktur embrio benih tidak menunjukkan perubahan signifikan sejak awal pematangan buah. Berdasarkan hal ini, terdapat hubungan timbal balik antara karakteristik morfologi dan fisiologis benih aren yang dorman. Semakin matang buah aren, semakin keras cangkang benihnya, sehingga dormansi benih semakin lama dan dikenal sebagai dormansi morfofisiologis.

Kata kunci: apocol, embryology, morphophysiology, ripening, sugar palm

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I. INTRODUCTION

The sugar palm stands out as a promising plantation crop with significant potential for development as a raw material for sugar palm and bioethanol production. It can be found across 14 provinces in Indonesia, with the largest cultivation area in West Java covering 13,135 ha (Natawijaya & Sunarya, 2018). Despite its multifunctional nature, the cultivation of the sugar palm has not been widespread, and it primarily relies on wild plants. In certain regions, this plant is a livelihood source, where palm sap is extracted to produce sugar palm. Moreover, the young fruits of the sugar palm can be harvested, and the flesh, referred to as "kolang-kaling," is utilized as an ingredient in various food and beverage preparations (Suhendra et al., 2023). Additionally, sugar palm serves as a valuable restoration plant for polluted lands, particularly those contaminated with heavy metals such as lead (Pb) (Rusnam et al., 2022) and zinc (Zn) (Rusnam & Efrizal, 2016).

The scientific name of sugar palm, locally known as aren, is *Arenga pinnata* Wurmb Merr. It belongs to the *Araecaceae* family, with the genus *Arenga*, in the sub-phylum *Angiospermae*. In various regions, this plant is referred to by different names, such as aren, aren palm, areng palm, arenga, arengga palm, or sugar palm. Morphologically, the sugar palm grows upright, featuring a round stem with a brownish-green color. Its leaves are arranged in a stem reset, with pinnate leaflets of light to dark green color. The flowers consist of male flowers fused in one cob, measuring 1-1.2 cm long. The fruit is elliptical with an inwardly curved tip, having a diameter of 3-5 cm. The sugar palm seeds are round and turn black when ripe (Sebayang, 2016). The seed development process in angiosperms typically initiates with double fertilization. In this process, one male cell fertilizes a haploid egg cell, while another fertilizes a homodiploid central cell in the ovule. This process produces diploid embryos and triploid endosperm (Zhang et al., 2021). Over the recent period, the population of sugar palms in their natural habitat has been declining due to aging trees that are no longer productive. The widespread exploitation of sugar palm trees for starch extraction contributes to this decline, especially in areas with a high concentration of sugar palm trees (Saleh et al., 2007). Regeneration of sugar palm trees poses a significant challenge, primarily due to the prolonged dormancy period of sugar palm seeds.

Sugar palm seeds are categorized as hard seeds with a germination period extending beyond three months from the ripening of the fruit. The ripening process of sugar palm fruit can exceed 24 months after anthesis. A noticeable morphological change during the ripening process is the shift in skin color from green to yellow or yellowish (Widyawati et al., 2010). To date, the criteria for physiological maturity have been established through physical observations of changes in fruit morphology and physiological assessments involving seed germination (Tresniawati et al., 2014). Understanding when seeds reach physiological maturity is crucial because, in this state, they are fully prepared to exhibit their optimal vigor. Seeds harvested before reaching physiological maturity generally have poor physiological quality (Pramono & Rustam, 2017), marked by a reduced germination ability (Widyawati et al., 2010). This is because the embryo lacks the maximum germination capacity, as the formation of food reserves still needs to be completed. Anatomically, mature sugar palm seeds include the endocarp, endosperm/albumen, and embryo, resembling the composition found in *Livistona rotundifolia* (Lam.) Mart (Viana et al., 2016). Sugar palm seeds, on the other hand, may take more than 3-5 months to germinate if the environmental conditions are not conducive. Techniques such as scarification (scraping the seed coat) or chemical soaking can accelerate the germination process in sugar palm seeds with dormancy to accelerate the germination process in palm seeds with dormancy (Aji & Syaputra, 2023). Widyawati et al. (2009) added that sugar palm seeds without scarification treatment produced

0% viability, while seeds with scarification through scraping using sandpaper on the back of the seed shell produced 67-82% germination.

One study mentioned that sugar palm seeds have a hard seed coat structure. The higher the fruit's maturity level, the skin's permeability decreases due to increase in lignin and tannin content. This impacts the difficulty of germinating sugar palm seeds (Widyawati et al., 2009). Furthermore, Elidar (2018) mentioned that some palm seed germination treatments were carried out on physiologically ripe palm fruit to obtain optimal results. Junaedi et al. (2020) also observed the anatomy of sugar palm seed germination, which showed different results in each genotype and maturity level. However, the research has not described how palm fruit's morphological, physiological, and anatomical characteristics at several maturity levels affect seed dormancy. The more mature the palm fruit is, the more it is suspected that morphologically, the skin of the palm fruit is getting harder, gibberellin levels are increasing, and changes in the embryo's position that affect seed dormancy. Therefore, it is important to investigate sugar palm seeds' morphological, physiological, and anatomical changes and their relationship with dormancy. This initial step is very important in determining the proper steps to accelerate the rejuvenation of sugar palm plants.

II. METHODS

The research was carried out during October and November 2023 in Nagari Andaleh Baruh Bukik, Sungayang Subdistrict, Tanah Datar Regency, West Sumatra, Indonesia (Figure 1), a renowned center for sugar palm production. Qualitative and quantitative methods were used to achieve the objectives of this research. Qualitative methods were used to determine the anatomical characteristics of sugar palm fruits and seeds. Quantitative methods were used on morphology and physiological characteristics. Morphological, physiological, and anatomical characteristics were observed at the Seed Science and Technology Laboratory, Faculty of Agriculture, Andalas University. Gibberellin hormone levels were assessed at the ICBB Laboratory, PT Biodiversitas Bioteknologi Indonesia, in Bogor, West Java.

Sampling was conducted using the purposive sampling method on 12 palm trees that have entered the productive period and produce palm fruit with a plant age of ±10 years. The selection of samples was carried out on several criteria, including strong trunk, dense leaves, and green to yellow fruit skin color. From the 12 plants selected, palm fruit was picked from several different bunches and then composited. Furthermore, the color of the palm fruit skin was grouped based on the maturity level, including M1 (dark green), M2 (light green), M3 (yellowish skin), and M4 (bright yellow). The color category of the fruit skin is based on the color code on the Munsell Color Chart for Plant Tissues (Table 1). Dark green skin is categorized as M1, light green to yellow skin is classified as level M2, yellowish skin is classified as level M3, and bright yellow to dark skin is classified as M4. Various equipment and materials for the research encompass measuring instruments (rulers), cameras, sugar palm fruits, and writing instruments. Anatomical observations were conducted using a microtome and oven. For hormone level monitoring, reagents and tools for gibberellin extraction were utilized. Environmental conditions during the observation were at a normal temperature of 25o C with a relative humidity of 65%.

Morphological observations were made on four samples of sugar palm fruit, including the thickness of the skin and shell of the palm seed and changes in skin color at each maturity level. Physiological observations were made to monitor changes in moisture content (Thermogravimetric Method) (Hakiki & Safitri, 2024), which is related to seed coat permeability, ash content (Gravimetric Method) (Pangestuti & Darmawan, 2021), crude protein (Kjeldahl Method) (Al Kausar & Suryani, 2022), crude fat (Soxhlet Method) (Pargiyanti, 2019), and carbohydrates (Luff Schoorl method)

(Ningrum et al., 2024) which are related to seed endosperm levels during the ripening process, which are related to the seed endosperm content during the ripening process of the palm fruit. Breaking the dormancy of sugar palm seeds is done through seed scarification by sanding the back of the seed shell and soaking it in water for 24 hours. Next, these seeds were germinated on moist cotton media. The emerged sprouts were categorized based on the level of fruit maturity and the position of apocol emergence, and their germination was observed. Physiological aspects were carefully examined, with a special focus on the level of the hormone gibberellin.

Anatomical preparations of sugar palm seeds were crafted using the paraffin method, involving the creation of longitudinal sections (Hamim et al., 2019; Nurhayani et al., 2019). The selected sugar palm seed samples were initially fixed in FAA solution, composed of 5 ml formalin, 5 ml glacial acetic acid, and 90 ml 70% alcohol. Subsequently, the samples underwent a series of steps, including dehydration, clarification, and infiltration. The samples fixed in FAA solution were washed with 50% alcohol four times, each lasting 1 hour. The dehydration was done by immersing the samples in the Johansen series solution. The paraffin

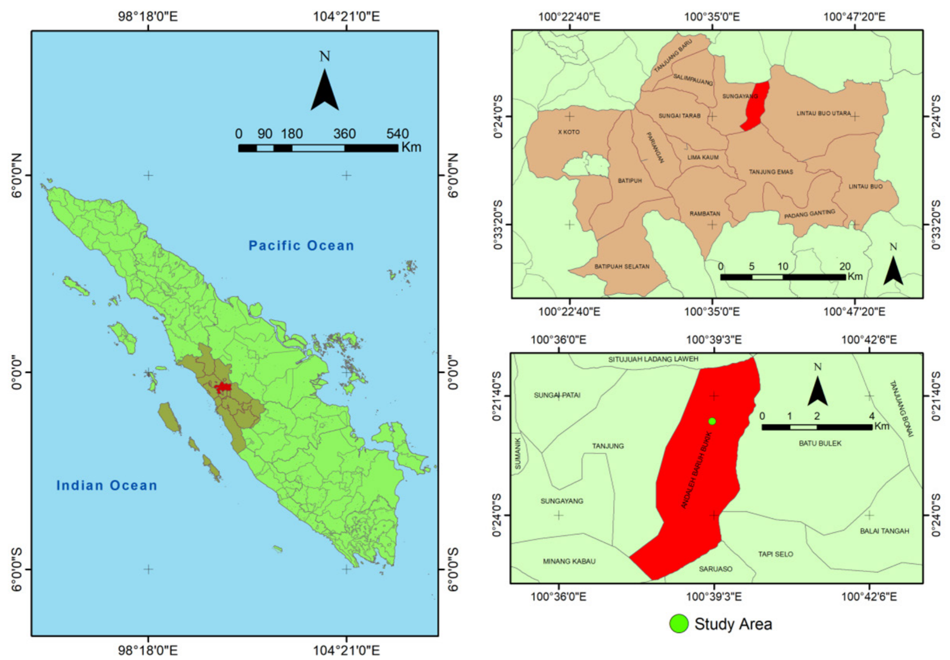

Figure 1. Research location in in Nagari Andaleh Baruh Bukik, Sungayang Subdistrict, Tanah Datar Regency, West Sumatra, Indonesia

Table 1. Color criteria of sugar palm fruit during ripening process using Munsell Color Chart for Plant Tissues

Visual color	Color criteria of sugar palm fruit		
	Hue	Value (ordinate)	Chroma (axis)
Dark green (M1)	5GY	4	4
Light green (M2)	2.5GY	6	8
Yellowish skin (M3)	5Y	8	8
Bright yellow (M4)	7.5YR	7	10

infiltration process occurs in several stages. Frozen paraffin is added to a container with the sample, tertiary butyl alcohol, and paraffin oil. The mixture is left open at room temperature for 1-4 hours and then continued in an oven at 60° C. Subsequently, the blocks are softened by immersing them in Gifford's solution for one week. Thin slices, approximately 10 μm thick, are obtained using a microtome. These paraffin slices are affixed to a glass object using a hot plate at 40° C for 3-5 hours. The subsequent step involves staining with 2% safranin and 0.5% fast green. The stained preparations are covered with a cover glass and observed under a binocular microscope at a specific magnification.

Physiological observations were made on seed germination parameters, especially gibberellin levels in sugar palm seed sprouts. Gibberellin levels were observed by the liquid chromatography method (Nefed'eva & Mazey, 2009). Standard solutions and reagents were gibberellin GA3 with 98% purity, methanol, 98% purity formic acid, distilled water, and a stock solution. Analysis was performed using high-performance liquid chromatography with a reverse-phase separation system equipped with an ultraviolet-visible detector (Shimadzu LC-AT20), 4.6 x 150 mm C18 (ODS) column (GL Science-Japan). The mobile phase used was 60% methanol and 40% water, based on the results of the mobile phase search optimization that had been carried out. The flow rate of the mobile phase was set at 0.5 mL min-1. The wavelength used in the KCKT system is 224 nm, based on the maximum wavelength reading that has been done. The sample was filtered using a 0.45 μ syringe filter and then injected into the KCKT instrument with an injection volume of 20 μ L for 40 minutes with isocratic separation conditions on the KCKT (Tsabitah et al., 2024).

The data obtained was input into Microsoft Excel software and then displayed as a histogram equipped with error bars. The difference in the results of each treatment can be seen in the high and low histograms displayed. Data on seed physiology observations, especially viability, were tested for normality and then subjected to analysis of variance (ANOVA). Significant differences in seed viability at each maturity level were further tested with Duncan's Multiple Range Test (DMRT), $\alpha = 0.05$. The analysis used R-Studio software.

III. RESULTS AND DISCUSSIONS

Lawu Mountain is situated between the CenThe sugar palm, classified in the Palmae family, is a sizable annual plant that can reach heights of up to 12 m with a stem diameter of approximately 65 cm. Its distinctive feature includes a crown of leaves that extends above the stem. The sugar palm fruit is suspended in branched clusters, attaining lengths up to 90 cm. The fruit exhibits a round shape, typical of the Palmae family. Notably, there are noticeable distinctions in the morphology of raw and ripe sugar palm fruits. In its raw state, the fruit's skin (exocarp) is green, transitioning to a yellow hue when fully ripe (Lempang, 2012). The research indicates that during the ripening of sugar palm fruit, there is a gradual transformation in the skin color from green to yellow. This transition is not immediate but occurs progressively, extending up to 24 months after anthesis (Widyawati et al., 2010). As a result, the overall ripening process can be categorized into four distinct levels.

Based on observations of the maturity level of sugar palm fruit and its physical and morphological characteristics, the stages of ripening until the seeds reach physiological maturity can be delineated as follows (Figure 2):

a) Maturity level 1 (M1): Sugar palm fruit exocarp exhibits a green to dark green.
b) Maturity level 2 (M2): The exocarp of sugar palm fruit appears light green to yellowish.
c) Maturity level 3 (M3): Sugar palm fruit exocarp takes on a yellowish hue.
d) Maturity level 4 (M4): Sugar palm fruit exocarp adopts a dark yellow to slightly reddish.

Figure 2. Changes in the color of sugar palm fruit skin during the ripening process

The sugar palm fruit's endocarp is notably thicker than to the exocarp. The endocarp, the fruit's white flesh, encompasses the embryo (ovule). Sugar palm seeds are deemed physiologically mature when their components, including the seed coat (testa), endosperm, and embryo, have undergone well-developed growth. The sugar palm fruit's testa tissue comprises sclereid cells, while the endosperm and embryo tissue consist of parenchyma cells. The testa portion constitutes dead tissue, while the endosperm contains some living cells. In contrast, the embryo predominantly comprises living cells that are physiologically active and retain substantial moisture content, crucial for sustaining the life of its constituent cells (Widyawati et al., 2009).

The color of the skin is often a primary indicator of the fruit's maturity or ripeness. The ripening process in sugar palm fruit typically begins with chlorophyll degradation, similar to in dates (Elbar et al., 2022). As the fruit ripens, the plant produces proteins and other vitamins, including ethylene, abscisic acid (ABA), and jasmonic acid. These compounds act as signals to the CCG gene (chlorophyll catabolic gene), hindering its performance. Subsequently, the biosynthesis of new pigments, such as carotenoids, occurs in the chromoplast, changing the fruit's color to yellowish or dark yellow (Kapoor et al., 2022).

Visually, the fruit ripening process presents a significant difference in the skin color of the sugar palm fruit. However, based on other morphological characteristics, such as the thickness of the palm seed shell at all maturity levels, averaged 0.4 mm at all maturities, with an endosperm diameter of 1.6-1.9 mm (Figure 3).

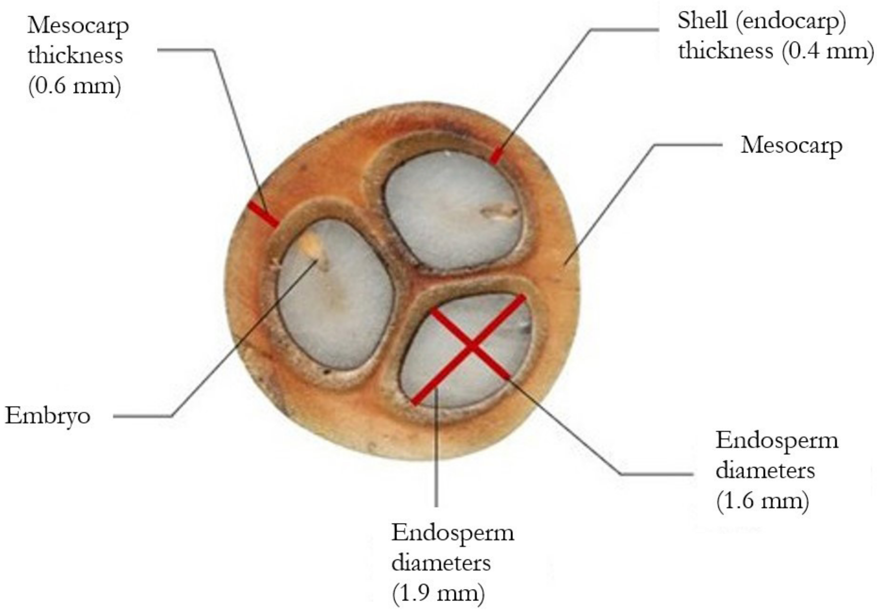

Figure 3. The structure of palm fruits and seeds and the thickness of their parts

Table 2. Viability of sugar palm seeds at different levels of maturity

Maturity levels	**Viability (%)**
Green (M1)	9.52 b
Yellowish green (M2)	17.72 b
Greenish yellow (M3)	27.72 a
Yellow (M4)	18.20 b
Coefficient of Variance	24.38%

Remark: Different letters in the same column indicate significant differences at the 0.05 according to the DMRT test.

However, the seed coat appeared to have a harder texture as the maturity level increased due to lignin accumulation. Physiologically, it can be seen that each maturity level gives different seed germination values (Table 2).

The analysis showed that the best viability of palm seeds was shown by the M3 maturity level, characterized by a greenish-yellow color of the fruit skin, where the viability reached 27.72% (Table 2). The M3 maturity level produced the length and diameter of the apocol and the diameter of the embryo, which amounted to 105.33 mm, 6.95 mm, and 767 μm until the 47th day of germination. Overall, the length and diameter of the apocol in the germinated seeds looked relatively the same at each maturity level. This indicates that there is no significant difference in the thickness of the seed coat, considering that each fruit has entered the ripening phase, but no color change has occurred. Widyawati et al. (2009) added that changing the color of palm fruit skin from green to yellow occurs gradually up to 2 years, even though it is in the same phase.

Furthermore, no fundamental difference in several parameters was observed, such as moisture content, fat content, carbohydrates, and so on, as illustrated in Figure 2. As described earlier, the palm kernels have entered the same level, namely the ripening phase, but changing the color of the fruit skin occurs gradually. In plants belonging to the Palmae family, the water content values generally decrease as fruit maturity increases. This phenomenon is observed in oil sugar palm fruit, which exhibits lower moisture content during the physiological ripening phase (Misron et al., 2017). Achieving physiological maturity is crucial for ensuring good seed quality, alongside other considerations, such as seed health, which involves being free from infections and contamination caused by disease pathogens (Anwar et al., 2005). Regarding the color of the seed coat, the different maturity levels did not give a significant change in color pattern (Figure 4). The palm seeds have the same color pattern, which is black-brown skin. This maturity level will have a significant influence on the germination process. Usually, seeds that have reached physiological maturity have optimal nutrient content to support germination. Conversely, not physiologically mature seeds tend to have low germination or even fail to germinate.

Figure 4. Color pattern of sugar palm seeds at different maturity levels

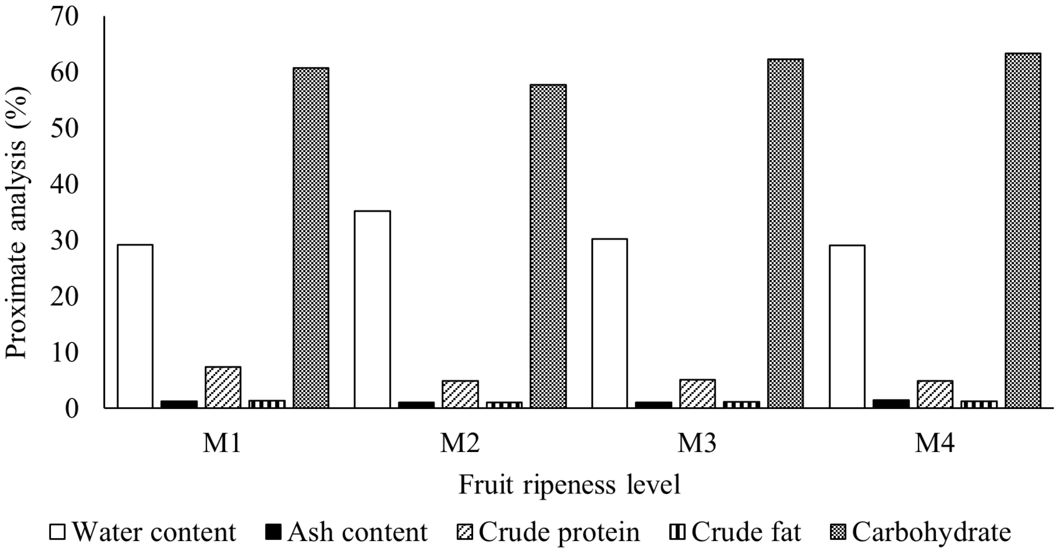

Figure 5. Changes in water content, ash content, crude protein, crude fat and carbohydrates during the sugar

Analyzing Figure 5 reveals notable trends in the sugar palm fruit's chemical composition during ripening. The water content exhibits a decreasing pattern from maturity level M1 to M4, suggesting slight physiological changes but not significant ones. Regarding ash content, M4 stands out with higher levels than M1, M2, and M3. Conversely, the protein content of M1 surpasses that of M2, M3, and M4. However, crude fat and carbohydrate content parameters do not exhibit significant value variations across maturity levels (Figure 5).

The findings of this test align with research on the proximate tests of sugar palm endosperm composition, as indicated by Torio et al. (2006). They reported that physiologically, ripe sugar palm fruit (aged 22-24 months after anthesis) tends to have lower water content, higher ash and fat content, and decreased fiber content. The description of water content generally characterizes the water status within plant tissue (Wisnubroto et al., 2020; Wisnubroto et al., 2021; Wisnubroto et al., 2024), including fruit. The observed decrease in water content in increasingly ripe sugar palm fruit could be attributed to the breakdown of carbohydrates into energy for the growth and development of sugar palm embryos.

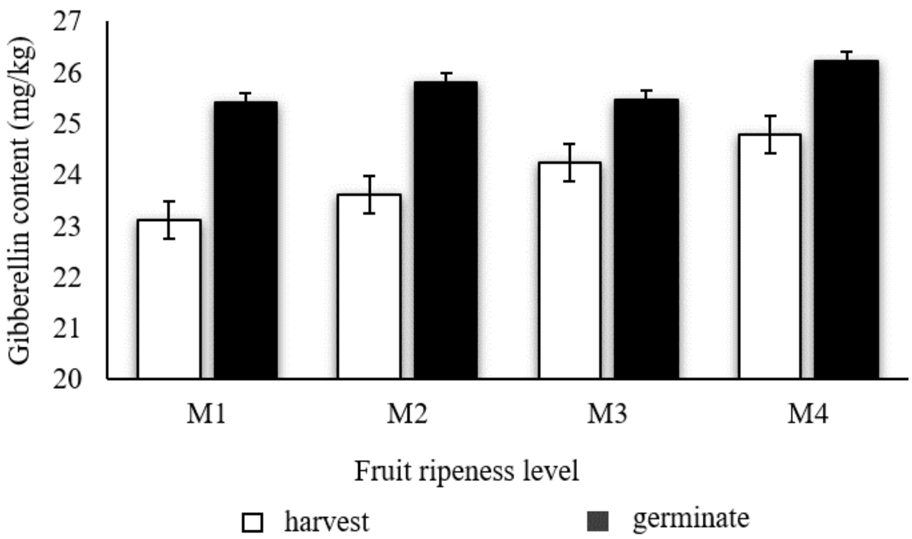

Figure 6. Gibberellin levels at various stages of maturity of sugar palm fruit and sprouts. Symbol (I) indicates the standard deviation of the observed data.

Figure 6 illustrates the gibberellin content during the ripening and germination process. Gibberellin is a crucial hormone that breaks dormancy and initiates cell division, enabling sugar palm seeds to germinate. This hormone is synthesized at the tip of the apical meristem or the actively dividing part of the plant. Gibberellins also play a vital role in elongating stem segments where the tips are still meristematic (Gupta & Chakrabarty, 2013). Additionally, alongside gibberellin, hormones like cytokinin and auxin stimulate cell division activity in roots and shoots, fostering accelerated germination (Anwar et al., 2018).

Figure 6 provides information indicating that the gibberellin levels increase with the higher maturity level of the fruit. The M4 stage of sugar palm fruit maturity exhibits higher levels of gibberellin hormone than M1, M2, and M3. Coincidentally, in this stage, there is a decrease in water content, as observed in Figure 4. A similar correlation was reported in a sugar palm seed technology study by Saleh et al. (2007). The M4 phase of sugar palm fruit maturity suggests that the fruit is physiologically ripe, and the seeds are prepared to germinate after successfully passing through or breaking the dormancy period. The M4 maturity phase during the germination of sugar palm seeds is characterized by high levels of the hormone gibberellin (GA), as depicted in Figure 6. The action of GA is in contrast with abscisic acid (ABA). GA stimulates germination through cell division, while ABA promotes seed dormancy. GA influences germination in two main ways: by enhancing the growth potential of the embryo and by inducing hydrolytic enzymes, particularly α-amylase. During seed germination, embryonic GA is released, initiating dormancy breaking by stimulating the expression of genes involved in cell expansion and modification (Gupta & Chakrabarty, 2013). Overall, observations on the relationship between palm fruit maturity level and germination variables are still limited to observation of gibberellin levels. However, several references show that the maturity level significantly effects the germination of palm seeds, germination rate, and vigor index. The more physiologically mature the seeds are, the higher their germination rate and vigor index. This is because physiologically ripe fruits contain enzymes that actively support germination. Aji and Syaputra (2023) added that sugar palm seeds derived from physiologically ripe fruit, characterized by an evenly yellow color, provide better seed growth uniformity than at other maturity levels. The same thing was also shown by Vanitha and Vasudevan (2019), which stated that fruits with a perfect maturity level with characteristics of evenly yellow skins provide optimal germination and germination rates compared to fruits that are not evenly yellow. However, the germination of sugar palm seeds is also influenced by the genotype of the palm plants. Junaedi et al. (2020) stated that varieties in the Pematang Siantar region have a germination rate of 75%, Bengkulu Curup 90%, Cianjur 98%, and East Kutai 89%.

The anatomical characteristics of sugar palm fruit are discerned through a longitudinal incision, followed by observation under a microscope at a specific magnification. This characteristic enables the description of the sugar palm fruit's tissue structure, including its internal parts. The outcomes of anatomical observations offer a relatively straightforward depiction of embryos still developing during maturation (Figure 7).

In general, the anatomy of the sugar palm fruit consists of the exocarp or skin (in the form of cuticle, epidermis, and hypodermis), as well as the mesocarp/endocarp (which is the flesh of the sugar palm fruit), and the embryo (ovule that will develop), as is the anatomy of the date palm fruit (Alsmairat et al., 2023). However, the exocarp of sugar palm fruit is mainly composed of sclereid cells, which are hard like the exocarp of oil palm fruit. Stone cells (sclereids) form sclerenchyma tissue, which develops through lignin deposition into the primary cell walls of parenchyma cells, causing an increase in cell wall thickness (Alsmairat et al., 2023). Figure 7 shows the embryo is situated in the deepest layer after the exocarp and endocarp. The embryo does not exhibit signs of undergoing a differentiation process, indicating that the sugar palm kernel attains physiological maturity during ripening while still being in the dormancy period. However, as illustrated in Figure 7.d., a meristematic part will eventually differentiate into cotyledons and radicles when the dormancy period concludes or transitions into the germination phase.

As germination progresses, meristematic cells with an irregular arrangement gradually emerge at the bottom of the embryonic cavity, accompanying the growth of the radicle (Luo et al., 2023). During germination, the embryo enlarges, and the endosperm diminishes. Cotyledons and radicles utilize these food reserves for their growth and development. The transition area between the plumule and radicle undergoes differentiation, giving rise to secondary roots, parenchyma cells, and a group of fiber tissue (Viana et al., 2016). It can be seen in Figure 8 that the germinated sugar palm seeds will show changes in the embryo. The embryo's position in the sugar palm seed is located on the left or right side of the seed back, with the characteristics of a round indentation on the back of the seed (Figure 8.a).

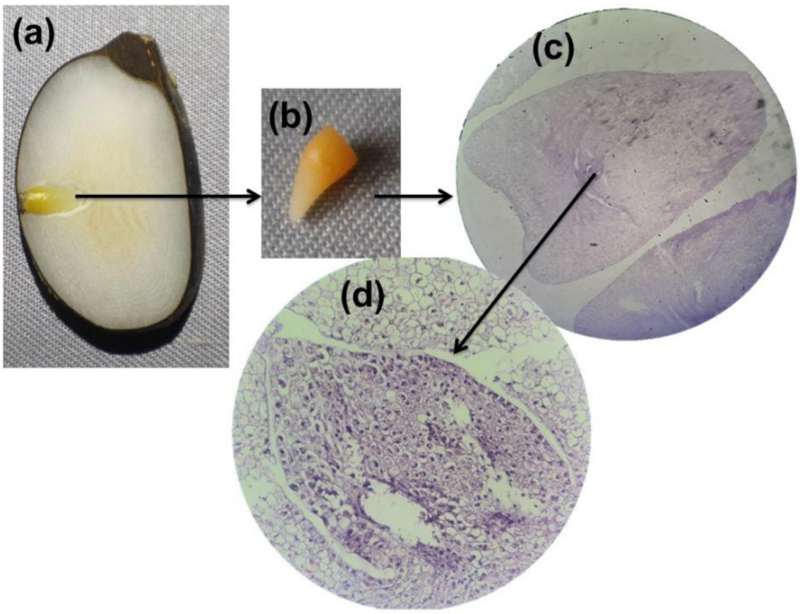

Figure 7. Longitudinal incision of sugar palm fruit seeds observed under a binocular microscope. a) the appearance of a longitudinal incision in the sugar palm seed; b) the sugar palm seed embryo; c) the appearance of sugar palm embryos under a microscope with 10X magnification; and d) the appearance of the future cotyledons and radicle at 40X magnification.

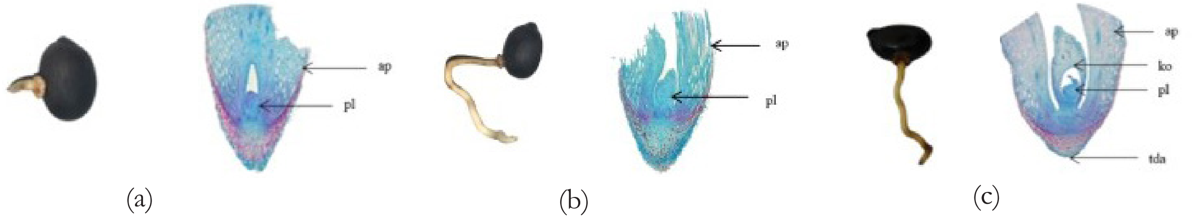

Figure 8. Anatomical development of germination of sugar palm seeds germinated at 10 days interval; a) 10 days; b) 20 days; and c) 30 days after germination; ap: apocol, pl: plumule, ko: coleoptile, tda: root cap.

After 10 days, there are differences in the morphology and anatomy of the germinated sugar palm seeds. The process begins with the appearance of white ring-like tissue on the scarified part (Figure 8.a.). This tissue will develop into a white tube-like shape known as apocol (growing through the operculum) (Figure 8). The apocol will continue to grow in length until the emergence of the primary root (Figure 8.b). As the embryo develops and the plumule (first leaflet) emerges, the diameter of the apocol will increase (Figure 8.b). By the 30th day, the embryo has clearly differentiated into a plumule and the emergence of coleoptiles in the apocol cavity (Figure 8.c). Coleoptile has a role as a plumule protector when it penetrates out of the apocol. Furthermore, the coleoptile will develop into a leaf, and the opening of the first leaf signifies the end of the seed's endosperm function as a food reserve (Suhendra et al., 2023). After 10 days, there will be a transition zone, so the radicle and plumule are clearly visible. The tip of the apocol that grows downward will form the primary root as the first sense (radicle) as shown in Figure 8.c. This primary root is covered by a root cap for protection when it penetrates the soil. The germination of sugar palm is classified as an epigeal type because the cotyledons will emerge to the soil's surface and become the plant's first leaves.

Generally, there is no observable change in anatomy or physiology from the M1 to M4 ripening phases, where water content, protein, and carbohydrate content consistently maintain high values throughout the entire sugar palm fruit ripening process. This prolonged maintenance of high values contributes to the relatively lengthy dormancy phase experienced by sugar palm seeds. Furthermore, based on anatomical information (Figure 7 and 8), it becomes evident that a specific technique or scarification of sugar palm seeds is necessary to shorten the dormancy period. This is crucial for facilitating efforts to germinate and rejuvenate sugar palm plants.

The results of this study significantly impact on sugar palm cultivation activities carried out by farmers. The level of fruit maturity can be an indicator for farmers to have palm fruits that are suitable to be used as planting material or seeds. In addition, it makes it easier for farmers to recognize the characteristics of palm fruits that have reached physiological maturity, thus helping select palm seeds with high germination potential. Physiologically mature seeds produce seeds with optimal germination, thus minimizing seedling failure. Information on seeds' morphological and physiological changes during maturation also allows the identification of the optimal maturity stage for seed harvesting. This is important to ensure high germination and good seedling vigor. These results also provide important basic information for plant breeding programs, especially in selecting superior genotypes based on physiological and anatomical characters of seeds that support the adaptation and productivity of sugar palm plants. During this research, obstacles became limiting factors in the study. One of them is the limited tools in the research. In addition, references or standard operating procedures for making cross-section sugar palm seed are still unavailable, and the number of seed samples used is still limited. However, the results of this study have been able to provide information that the dormancy of sugar palm seeds does not come from outside (exogenous dormancy type) but is caused by embryo differentiation that does not occur during the maturation and germination process. In the future, efforts to break the dormancy of sugar palm seeds should be made mechanically by breaking the hard skin and considering the morphophysiological aspects of sugar palm seeds.

IV. CONCLUSIONS

Ripening of the sugar palm fruit initiates the transition of the skin color from green to yellow. However, this color change is not accompanied by a change in the shell of the palm fruit or the size of the seeds, only the hardened shell of the seeds. Physically, important changes occur in water, carbohydrates, protein, and fat content. In addition, there is considerable variation in the gibberellin hormone content of the palm seeds during the ripening and germination phases. From an anatomical perspective, it is clear that embryo differentiation does not occur during the maturation and germination process. The structure of the sugar palm seed embryo remains consistent, especially from the beginning of ripening until the start of the germination process. There is a reciprocal relationship in which the higher the maturity level, the harder the seed coat structure. This condition is believed to be the main cause of sugar palm seed dormancy, which is categorized as morphophysiological dormancy. Overall, the maturity level of M3 is considered optimal for use as planting material for sugar palm cultivation.

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FEASIBILITY ANALYSIS OF MULTI-BUSINESS FORESTRY IN SOCIAL FORESTRY IN FOREST AREAS WITH SPECIAL MANAGEMENT (KHDPK)

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FEASIBILITY ANALYSIS OF MULTI-BUSINESS FORESTRY IN SOCIAL FORESTRY IN FOREST AREAS WITH SPECIAL MANAGEMENT (KHDPK). The concept of multi-business forestry (Mb-F) aims to increase the economic benefits of forests, which have thus far made little contribution, without ignoring their ecological functions. The opportunity to develop multi-business forestry in social forestry (SF) activities within the Forest Area with Special Management (*Kawasan Hutan Dengan Pengelolaan Khusus*/ KHDPK) is huge. With one area management permit, many business activities can be carried out. This study aims to determine the feasibility of multi-business forestry using screening method for social acceptance (community preference), financial feasibility (NPV, B/C Ratio, and IRR), and ecological suitability (soil type, rainfall, and location altitude). The results show that socially, the community accepts and has even implemented the concept of multi-business forestry through agroforestry. However, most permit holders consider it necessary to regulate the number of trees to optimize land use. Economically, all multi-business patterns implemented are feasible, with the presence of aren (Arenga pinnata) and sheep being important keys to the sustainability of SF. Ecologically, some NTFPs species cultivated by the community are less suited to local conditions, which can result in suboptimal production. The existence of investors or business entities is very important in the sustainability of forestry multi-businesses, which are mostly based on NTFPs and require high capital.

Keywords: Multi-business forestry, social forestry, social acceptance, financial feasibility, ecological suitability

ANALISIS KELAYAKAN MULTIUSAHA KEHUTANAN DALAM SKEMA PERHUTANAN SOSIAL PADA KAWASAN HUTAN DENGAN PENGELOLAAN KHUSUS (KHDPK). Konsep Multi Usaha Kehutanan (MUK) dimaksudkan untuk meningkatkan manfaat ekonomi hutan yang selama ini belum banyak memberikan kontribusi, tanpa mengabaikan fungsi ekologisnya. Peluang pengembangan multi usaha kehutanan dalam kegiatan perhutanan sosial (PS) di Kawasan Hutan Dengan Pengelolaan Khusus (KHDPK) sangat besar. Dengan satu izin pengelolaan kawasan, banyak kegiatan usaha yang dapat dilakukan. Penelitian ini bertujuan untuk mengetahui kelayakan multi usaha kehutanan dengan menggunakan metode penyaringan penerimaan sosial (preferensi masyarakat), kelayakan finansial (NPV, B/C Ratio, dan IRR), dan kesesuaian ekologi (jenis tanah, curah hujan, dan ketinggian lokasi). Hasil penelitian menunjukkan bahwa secara sosial masyarakat menerima, bahkan telah melaksanakan, konsep multi usaha kehutanan melalui agroforestri. Namun, sebagian besar pemegang izin menganggap perlu adanya pengaturan jumlah pohon agar lahan dapat dimanfaatkan secara optimal. Secara ekonomi, semua pola usahatani yang telah dilaksanakan layak untuk dijalankan, dengan keberadaan aren (Arenga pinnata) dan domba menjadi kunci penting keberlanjutan PS. Secara ekologi, beberapa jenis HHBK yang dibudidayakan oleh masyarakat kurang sesuai dengan kondisi ekologi setempat, sehingga dapat mengakibatkan produksi yang kurang optimal. Keberadaan investor atau badan usaha sangat penting dalam keberlanjutan usahatani kehutanan yang sebagian besar berbasis pada HHBK serta membutuhkan modal yang tinggi.

Kata kunci: *Multi-usaha kehutanan, perhutanan sosial, penerimaan sosial, kelayakan finansial, kesesuaian ekologi*

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I. INTRODUCTION

The forestry sector was once Indonesia's mainstay, contributing significantly to GDP after the oil and gas sectors. Conditions have now changed considerably. The forestry sector contributed approximately 3.5% to Indonesia's national income and provided livelihoods for around 15 million people in 1997 (Central Statistics Agency, 2000), but this fell to 2.3% in 2002 (Central Statistics Agency, 2003). However, this contribution has declined due to challenges such as illegal logging and insufficient investment in sustainable practices (Malahayati, 2018; Sahara et al., 2022). According to Nurrochmat et al. (2021), the forestry sector's contribution to Indonesia's GDP is only around 0.6%. This condition certainly makes the forestry business unattractive to investors.

Moreover, while investment in the forestry sector can enhance output and employment, it also raises the demand for raw materials, potentially increasing imports (Sahara et al., 2022). Economic growth and deforestation are complex; improved forest management has been linked to economic development, yet high deforestation rates remain a concern (Malahayati, 2018). Thus, while the forestry sector is vital for Indonesia's economy, its sustainability and future contributions depend on addressing these critical challenges.

In addition, the forestry sector is also considered to have contributed less to the economy of communities around the forest. For this reason, the government runs various community involvement programs in forest management, one of which is through social forestry (SF). Social forestry, an approach that involves community participation in forest management, has garnered significant attention as a sustainable strategy for balancing environmental conservation and local livelihoods. As the global focus shifts towards sustainable development, the sustainability of social forestry becomes crucial.

A more varied and sustainable type of forest management is replacing timber-centric methods in Indonesia with multi-business forestry (Mb-F) (Suryanto et al., 2023). By combining timber production with non-timber forest products (NTFPs) and environmental services, this idea seeks to maximize the use of forests (Mutaqin et al., 2023). Obstacles to Mb-F implementation include complicated bureaucratic processes, frequent policy changes, and regulatory ambiguity (Pambudi, 2023). However, it also offers better land use, jobs, and biodiversity preservation (Suryanto et al., 2023). To promote sustainable forest management and enhance livelihoods, social forestry initiatives that entail community engagement are being pushed (Pambudi, 2023). Addressing illicit logging and improving forest governance in Indonesia has benefited greatly from international collaboration, such as the Multistakeholder Forestry Programme with the UK (Ridho et al., 2019).

The Forest Area with Special Management (KHDPK) issuance, as a derivative of the Job Creation Law, seeks to optimize the performance of social forestry in Java while improving land rehabilitation. The KHDPK concept also aims to adopt multi-business forestry practices. KHDPK opens up opportunities for the forestry sector to contribute more economically, especially to the community. This opportunity can be realized through multi-business forestry practices, where several business activities exist in one location or the same management permit. The success and sustainability of forestry multi-businesses are influenced by three main factors, namely, 1) social acceptability, 2) financial feasibility, and 3) ecological suitability (Nurrochmat et al., 2021). These factors determine the success of SF implementation.

Social acceptability is crucial in social forestry programs as it influences the effectiveness and sustainability of forest management practices. Research indicates that social acceptability encompasses community trust and values, essential for gaining a social license to operate in forestry contexts (Ford & Williams, 2016). This concept highlights the need for inclusive dialogue to develop a forestry model accommodating diverse stakeholder interests. Furthermore, social forestry is often more culturally and socially acceptable than large-scale forestry, promoting local participation and holistic land use (Santiago et al., 2022). However, challenges such as high initiation costs and the need for community development institutions can impede progress (Santiago et al., 2022). Thus, understanding and integrating social acceptability into forestry initiatives is vital for fostering community support and ensuring long-term success.

Financial feasibility is also an essential aspect of social forestry, with studies showcasing the benefits of small-scale community forestry regarding financial gains and sustainable practices (Hunt, 2002). Understanding the financial implications of forestry practices is essential for evaluating the viability of investments and ensuring long-term economic sustainability (Callaghan et al., 2019). Research has demonstrated that financial support and incentives significantly enhance green total factor productivity in forestry, highlighting the importance of financial mechanisms in promoting sustainable forestry practices (Wu, 2023). Moreover, Astuti et al. (2020) said that social forestry is a program that aims to reduce poverty and inequality in forest use by providing legal access to local communities.

Moreover, land suitability is a fundamental determinant of the ecological sustainability of social forestry. The success of social forestry projects largely depends on selecting the right species and crops that align with an area's specific climatic and soil conditions. Land suitability plays a crucial role in determining the success of social forestry initiatives, especially regarding crop selection and agroforestry patterns (Faadhilah et al., 2023). Moreover, the profitability of environmental activities in forestry enterprises underscores the economic viability of integrating sustainability measures (Zamula et al., 2020).

Integrating farmer acceptance, financial feasibility, and ecological suitability is essential for the comprehensive planning and implementation of social forestry projects. Successful integration can lead to enhanced biodiversity conservation, improved livelihoods, and greater resilience to climate change. For instance, carefully selecting tree species based on land suitability and farmer preferences can enhance ecosystem services such as soil stabilization, water regulation, and carbon sequestration (Kumar & Bhattacharya, 2021). Additionally, economically viable models considering market dynamics can ensure that social forestry remains profitable for local communities.

Previous studies generally only discuss one aspect: economic, social, or environmental. In addition, as a new policy, there has been no research that assesses the three aspects of sustainability in Multi-business Forestry (Mb-F) in Social Forestry in KHDPK. This paper fills these gaps by examining three core aspects of social forestry: social acceptability in the form of farmer preferences for crop species, land suitability, and financial feasibility. Each factor is pivotal in determining social forestry initiatives' long-term success and sustainability. Business sustainability is one of the keys to success in implementing SF in KHDPK.

II. RESEARCH METHOD

A. Research Location

This research was conducted in Ciamis Regency and Pangandaran Regency, West Java Province. The research area in the two districts is the former Ciamis Forest Management Unit (FMU) area, managed by Perum Perhutani as a KHDPK area. KHDPK in West Java Province covers an area of around 338,944 ha, originating from 163,427 ha of Production Forest and 175,517 ha of Protected Forest, with about 8,129 ha located in the former Ciamis FMU (BPKHTL Wilayah XI, 2024). The research was conducted on five farmer groups in Golat Village, Panumbangan Sub-

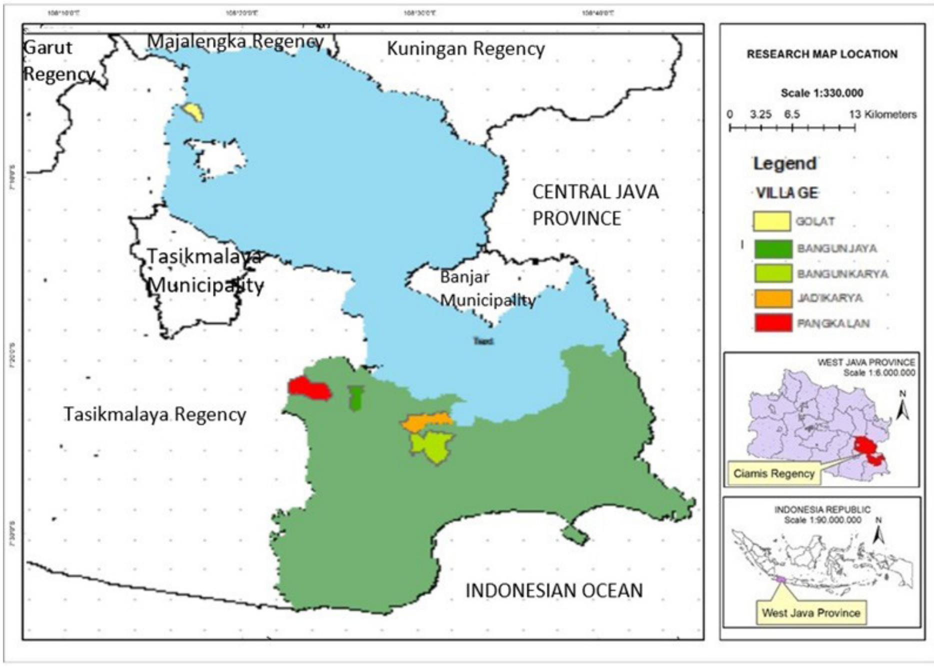

Figure 1. Research locations in Ciamis Regency and Pangandaran Regency

District, Ciamis Regency, Bangunjaya Village, Pangkalan Village, Bangunkarya Village, and Jadikarya Village in Langkaplancar Sub-District, Pangandaran Regency. The SF scheme for the forest farmer group in Jadikarya Village is community forestry (*Hutan Kemasyarakatan*/HKm). In contrast, the other four forest farmer groups use the Village Forest (*Hutan Desa*/HD) SF scheme. The main difference between HD and HKm is in the target community. HKm is intended for communities living around forest areas that depend on these natural resources for their economic needs, such as for agriculture or plantations. The reason for choosing the location is that in the former Ciamis FMU, the five farmer groups have obtained SF management permits at KHDPK. Therefore, the population sampling was carried out by census. The research was conducted for four months, from April to July 2024. The research location can be seen in Figure 1.

Based on the altitude, Golat Village is located on a high altitude between 800-1000 m asl. While the other four villages are at medium and low altitudes. Bangunjaya Village, Pangkalan Village, Bangunkarya Village, and Jadikarya Village, Langkaplancar Sub-district, are 500 m asl, 600 m asl, 450 m asl, and 350 m asl, respectively.

B. Research Respondents

The farmer groups were selected purposively; five forest farmer groups (*Kelompok Tani Hutan*/KTH) and village forest management institutions (*Lembaga Pengelola Hutan Desa*/LPHD) that had obtained KHDPK permits in the former Ciamis FMU area were taken as the population. Former Ciamis FMU is an area whose management was transferred from Perhutani to MoEF and administratively covers three regencies/cities: Ciamis, Pangandaran, and Banjar. In each farmer group, interviews were conducted with 30 respondents selected by random sampling, so that the total number of respondents was 150 people. Key informants were selected, representing farmer group leaders and local champions. Farmer group champions were farmers who successfully implemented multi-business forestry in the research area. One group champion was taken from each farmer group.

C. Data Collection and Analysis

The multi-forestry business sustainability assessment was carried out using a sustainability

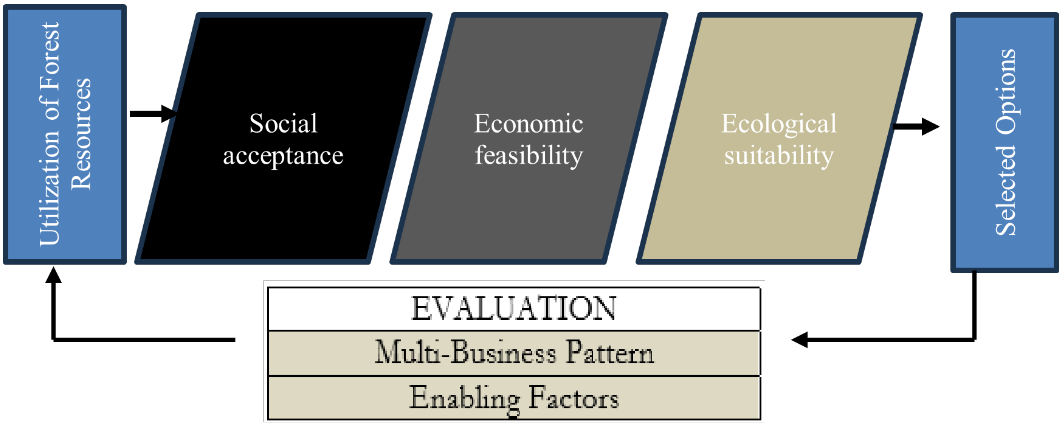

Figure 2. Concepts and stages in forest utilization selection (Nurrochmat et al., 2021)

assessment approach using a screening method, according to Nurrochmat et al. (2021). In using forest areas, this study analyzes social, economic, environmental, and supporting factors that can encourage the implementation of forestry multi-businesses (Nurrochmat et al. 2021). These stages are interrelated, so each process has a significant position, as seen in Figure 2.

The stages in assessing the feasibility of forestry muti-business consist of three stages, namely:

a) Identifying social acceptability in the form of choices (preferences) of the community and other stakeholders regarding the plant species used in SF activities. These types of plants are wood, multipurpose tree species (MPTS), and intercropping plants. These preferences indicate the community's social acceptance of the SF program.
b) Identifying the financial feasibility of SF business. The economic feasibility of using multi-business forestry to optimize land use is carried out using the Net Present Value (NPV), Benefit Cost Ratio (BCR), and Internal Rate of Return (IRR) approaches.
c) Identifying the ecological suitability of their growing locations and biophysical characteristics.

D. Identifying enabling factors

It is vital to consider some auxiliary aspects when applying a model to the field's contextual conditions, such as the institutional, social, economic, and biophysical (Mutaqin et al., 2023). In keeping with this, this study finds and examines enabling elements that can facilitate the application of knowledge—in this example, forestry multi-business—by the government as policymakers, by actors in the community, or by entrepreneurs. These elements should also inspire business owners and other forestry industry participants to become more aware of the financial landscape and take the initiative to put this forestry multi-business model into practice (Mutaqin et al., 2023).

III. RESULT AND DISCUSSION

Integrating the social forestry scheme or joint forest management with the community in multi-business forestry activities theoretically has a robust economic basis (Nurrochmat, 2021). Multi-business forestry is the implementation of several forestry business activities in the form of area utilization businesses, wood and non-wood forest product utilization businesses, and environmental service utilization businesses to optimize forest areas in protected forests and production forests. Multi-business forestry aims to increase forest value (Ministry of Environment and Forestry, 2023).

The Multi-business Forestry (Mb-F) concept requires cooperation between the government and the community in forest resource management. This condition is due to the government's limited resources to manage forests. According to Nurrochmat (2021), the initial costs for this activity are significant, but as the area managed increases, it will be efficient. Multi-business forestry in SF in KHDPK can be done through agroforestry patterns. Agroforestry integrates forestry and agricultural plants to accommodate short-, medium-, and long-term economic interests while improving ecological conditions. Agroforestry is vital in social forestry as it enhances community livelihoods, promotes environmental sustainability, and supports biodiversity. It integrates trees with crops, providing alternative income sources and improving food security for rural populations, as evidenced by the management of coffee agroforestry systems in Indonesia, which allows for shade-tolerant crops to thrive under tree canopies.

A. Social Acceptance

Social acceptability is indicated by two things, namely, community participation and the selection of plant species according to community preferences. Community participation in KHDPK has been realized through community cultivation activities, including granting SF permits in KHDPK. Farmers' preferences for certain species are influenced by two main factors: the suitability of the growing location and the economically profitable types (Widiyanto, 2024). These two factors are also influenced by the experience of farming that has been carried out for generations. However, not all farmers can plant according to their choices because there are limitations regulated in the SF agreement. In addition, not all species have been cultivated by farmers, so sometimes farmers resist certain species. Farmer preferences for crop species significantly influence the sustainability of social forestry. Moreover, understanding these preferences helps in designing programs that meet the needs of local communities, ensuring their active participation and long-term commitment. The selection of plant species at the research location is presented in Table 1.

Table 1. Plant species at the research location

Village	Trees (Perennial)	Multipurpose tree species/non-wood forest product	Annual crops
Golat	*Pinus merkusii* (Pinus) *Eucalyptus* sp.(Eucalyptus) *Altingia excelsa* (Rasamala)	*Coffea arabica* (Kopi Arabica), *Coffea canephora* (Kopi Robusta), *Arenga pinnata* (Aren)	
Bangunjaya	*Swietenia mahagoni* (Mahoni), *Toona sureni* (Suren)	*Coffea canephora* (Kopi Robusta), *Arenga pinnata* (Aren), *Amomum cardamomum* (Kapulaga)	*Capsicum frutescens* (Cabai)
Bangunkarya	*Swietenia mahagoni* (Mahoni)	*Durio zibetinus* (Durian), *Elettaria cardamomum* (Kapulaga)	*Capsicum frutescens* (Cabai)
Pangkalan	*Swietenia mahagoni* (Mahoni), *Toona sureni* (Suren)	*Coffea canephora* (Kopi Robusta), *Arenga pinnata* (Aren), *Amomum cardamomum* (Kapulaga)	*Manihot esculenta* Crantz (Singkong)

Village	Trees (Perennial)	Multipurpose tree species/non-wood forest product	Annual crops
Jadikarya	*Swietenia mahagoni* (Mahoni)	*Durio zibetinus* (Durian),	*Manihot esculenta* Crantz (Singkong), *Capsicum frutescens* (Cabai), *Nicotiana tabacum* L.(tembakau), *Vigna unguiculata* ssp. Sesquipedalis (kacang panjang)

The selection of tree and plant species in social forestry programs significantly impacts their success. Involving communities in selecting species based on their preferences can enhance the effectiveness of these initiatives. For example, certain species, like coffee plants in agroforestry systems, have been recognized for their contributions to social forestry programs and climate change mitigation (Kusumaningrum et al., 2024). It is crucial to align species selection with community needs and preferences to maximize the impact of social forestry on communities and forest areas (Rinaldi et al., 2024). Choosing species for reforestation in diverse forest communities requires balancing social preferences and ecological suitability (Chechina & Hamann, 2015). Native tree species are recommended for reforestation programs due to their adaptability to the environment, which can reduce the risk of project failure (Lillo et al., 2021). Additionally, when using exotic species in forest management, obtaining social acceptance from local communities is essential for sustainable operations (Rivera et al., 2016).

Farmers' choice of crop species plays a crucial role in the success of social forestry programs by influencing aspects such as carbon storage, biodiversity maintenance, and economic development. Farmers' preferences in selecting crop species and cropping patterns are crucial as they impact the success of land management, the earth's temperature level, and minimizing the effects of global warming (Novasari et al., 2023b). Diverse agroforestry systems have been identified as a sustainable land use option providing ecosystem services, habitat for biodiversity, and economic development for forest-dwelling communities in Southeast Asia (Willmott et al., 2023). In addition, the diversity of plant species in community forestry initiatives indicates forest conservation and environmental function, with farmer characteristics influencing the selection of plant types and planting patterns (Novasari et al., 2023b).

B. Economic Feasibility

NPV, BCR, and IRR indicators measure economic feasibility. Multi-business forestry activities in social forestry in KHDPK in the two research districts vary widely. However, several business activities are carried out by the community in a particular village. The patterns of multi-business forestry found in the research location can be seen in Table 2.

In this calculation, the main plants (trees), namely pine and mahogany, are assets of Perum Perhutani that are not handed over to the community or the Ministry of Environment and Forestry (MoEF). When conducting business in KHDPK, most of the land already contains these tree stands, although the amount per hectare varies greatly between villages. Despite having the highest NPV and IRR, durian-based SF does not have the highest B/C ratio. This condition is because the durian business requires large capital to purchase and maintain

Table 2. Economic feasibility of multi-business forestry in research location

Village	The multi-business forestry pattern implemented	Economic indicator		
		NPV	B/C Ratio	IRR
Golat	Pine-coffee-aren-sheep	IDR 93,016,474	1.91	25%
Bangunjaya	Mahogany-coffee-sheep-chilli	IDR 85,803,851	1.26	24%
Bangunkarya	Mahogany- durian-cardamom- sheep	IDR 198,742,339	1.52	27%
Pangkalan	Mahogany-aren-cardamom-sheep	IDR 104,734,442	2.04	28%
Jadikarya	Durian-sheep/goat-fish-chili-cassava-vegetables	IDR 970,201,425	1.72	29%

seedlings. The position of the durian plant in KHDPK replaces the role of mahogany. After 5-6 years of age, the durian tree has the same diameter and crown width and functions as other woods, such as mahogany. Among the types of NTFPs, cardamom can be harvested the fastest, namely in the 2nd year, followed by coffee in the 3rd year, durian in the 5th year, and sugar palm (aren) after the 10th year.

Interestingly, businesses that use aren as one of the NTFPs have higher profits than other types of NTFPs. Aren does not require difficult and expensive maintenance. In addition, unlike other NTFPs, almost all parts of the aren plant can also be used, starting from the sap (as a drink or sugar), the fruit, the leaves, the leaf veins, and the stem (Ministry of Agriculture, 2013). The presence of sheep or goats is also important in SF at KHDPK. Before the NTFPs can be harvested, sheep are an important source of income. Land clearing activities are also a feed source, and livestock manure can be organic fertilizer.

Financial feasibility is a crucial component in assessing the sustainability of social forestry. Projects must be economically viable for communities to adopt and sustain them. This includes initial investment costs, potential income from forest products, and the availability of financial support mechanisms such as subsidies or loans. Studies have shown that monetary incentives and access to markets significantly enhance the economic attractiveness of social forestry (Mankhin et al., 2023). Moreover, generating a steady income from forest products can provide financial security for rural households, reducing their dependency on more destructive land-use practices.

The presence of investors in SF based on NTFPs, such as durian, is an important key to this activity because the price of durian seedlings is high, about IDR 200,000-IDR 500,000. Providing forest farmers with access to resources and capital through programs such as the Revolving Fund Facility (*Fasilitas Dana Bergulir*/FDB) can have a positive impact on their economic well-being and the overall success of social forestry initiatives (Oktoyoki et al., 2023). The selection of crop types by farmers is critical to the success of social forestry programs, as it impacts sustainability, biodiversity, and economic viability within forest farmer groups (Rachmawan et al., 2022).

C. Ecological Suitability

Assessing land suitability for specific crops is essential for optimizing resource use and ensuring the long-term viability of agroforestry systems (Faadhilah et al., 2023). Knowledge, local practices, and economic considerations influence farmers' preferences for crop types and agroforestry patterns (Novasari et al., 2023b). Understanding these preferences is vital for designing sustainable land management strategies that align with community needs and environmental conservation goals (Novasari et al., 2023b). Additionally, adopting agroforestry practices is contingent upon farmers' perceptions and the compatibility of management practices with local populations (Arage, 2021).

Ecological suitability is assessed based on the suitability of soil type and rainfall. In addition, the research location is in a production and limited production forest, where the slope of the land is generally still suitable for cultivation activities. The results of the ecological suitability were then compared with the types of plants planted by farmers. The ecological suitability of the research location can be seen in Table 3. The types of plants evaluated are the most widely cultivated by the community. The location altitude of Bangunjaya Village, Pangkalan Village, Bangunkarya Village, and Jadikarya Village, Langkaplancar Sub-district, is 500 m asl, 600 m asl, 450 m asl, and 350 m asl, respectively. The soil type in the four villages is red-yellow podzolic soil that is acidic with a pH value below 6. This acidic soil type tends to have a lower cation exchange capability (CEC) due to the high concentration of hydrogen ions (H^+).

Red-yellow podzolic soil is formed in areas with high rainfall and high temperatures. This soil is generally formed from the pedogenesis of silicate crystals with poor chemical properties. Rainfall in these four villages ranges from 3500-4500 mm year-1. Golat Village has an altitude of 800-1000 m asl. Meanwhile, the soil type in Golat Village, Panumbangan Sub-district, is the Andisol type. This soil type has high organic matter content, low bulk density, high air retention capacity, and high total porosity. Still, this soil is also loose in consistency, less plastic, and not sticky. Rainfall in this village is +/- 2500 mm year-1 (Central Statistics Agency of Ciamis Regency, 2023; Central Statistics Agency of Pangandaran Regency, 2023).

Table 3. Ecological suitability of main plant species at the Research Location

Main plant species	**Optimal growth requirements**			**Evaluation of suitability at the research location**
	Rain intensity (mm/year)	**Soil type/ requirement**	**Altitude (masl)**	
Durio spp. (Durian) (Ministry of Agriculture, 2021)	1,500– 2,500	Fertile sandy loam soil	Up to 800 m asl	The altitude is suitable (except for Golat Village), but the rainfall is too high, and the soil type is less appropriate.
Coffea arabica (Kopi Arabica) (Ministry of Agriculture, 2014)	1,500- 4,000	Thick topsoil layer, high nutrient and organic content. The recommended average soil pH is 5-7	>900 m asl	Rainfall, soil conditions, and altitude are suitable for Golat village.
Coffea canephora (Kopi Robusta) (Ministry of Agriculture, 2014)	1,500 -3,500		<700 m asl	Rainfall is higher than optimal. Soil types are less suitable (four villages other than Golat)

Main plant species	Optimal growth requirements			Evaluation of suitability at the research location
	Rain intensity (mm/year)	Soil type/ requirement	Altitude (masl)	
Arenga pinnata (Aren) (Ministry of Agriculture, 2013)	>1,200	Clay, muddy, sandy	9-2,000 m asl	Suitable for all villages
Amomum cardamomum (Kapulaga) (Ministry of Agriculture, 2019)	2,500– 4,000	Soil with a clay texture, clayey loam, sandy loam, silty loam, and sandy clay	300-800 m asl	All villages meet the criteria except Golat Village

The table above shows that, based on the preferences of the types planted by the community in the social aspect, not all are suitable when assessed from an ecological suitability perspective. Of the five main plant species owned by the community, three of them are ecologically suitable, namely *Coffea arabica* (Arabica Coffee) in Golat Village, *Arenga pinnata* (Aren) in Golat Village, Pangkalan Village, and Bangunjaya Village. Two other villages, Bangunkarya and Jadikarya, are also found aren although the amount is not as much as in the other three villages. Farmers prefer to plant durian, which is considered more profitable. Moreover, *Amomum cardamomum* (Cardamom) is in Bangunjaya Village, Pangkalan Village, and Bangunkarya Village. The other two species, *Coffea canephora* (Robusta Coffee) in Golat (due to the altitude), Pangkalan Village (too high rainfall), and *Durio* spp (Durian) in Bangunkarya Village and Jadikarya Village, are categorized as less suitable due to high rainfall and less fertile soil. The unsuitability of these conditions does not mean that the plants do not grow or do not bear fruit. It is just less than optimal. For example, longer fruiting time or lower productivity. Farmers can intervene to overcome this, for instance, by fertilizing or intensive maintenance, although this treatment requires additional costs.

Land suitability plays a critical role in the success of social forestry programs by determining the optimal plant species to be cultivated based on the bio-geophysical characteristics of the land. The study emphasized the importance of matching land mapping unit (LMU) characteristics with plant growth needs to improve land productivity and community prosperity (Soraya et al., 2022). Evaluating the suitability level of different land uses for agroforestry systems contributes to sustainable land resource management in rural areas, ensuring the preservation of nature reserves from degradation (Chuma et al., 2021). Utilizing multi-criteria decision analysis for land suitability in selecting optimal locations for establishing forest plantations increases the likelihood of success by aligning ecological requirements with soil potential and climate conditions (Hernández-Zaragoza et al., 2019).

D. Identifying Enabling Factors

D.1.Regulative factors

The existence of multi-forestry businesses, especially in the KHDPK area, is supported by several laws and regulations. The regulations that support multi-forestry businesses in KHDPK include 1) Government Regulation Number 23 of 2021 concerning Forestry Implementation, 2) Regulation of the Minister of Environment and Forestry No. 9 of 2021 concerning Social Forestry Management, 3) Decree of the Minister of Environment and Forestry No. 287 of 2022 concerning KHDPK, and 4) Regulation of the Minister of Environment and Forestry No. 4 of 2023 concerning Social Forestry Management in KHDPK. If the community had only been

Table 4. Activities in social forestry at KHDPK according to applicable regulations

No	Activity categories	Types of supporting activities for forestry multi-enterprise
1	Utilization of wood forest products	1. Tree cultivation (for Community Plantation Forest/HTR scheme) 2. Multipurpose tree (MPTs) cultivation
2	Utilization of non-wood forest products	Utilization and collection of rattan, sago, aren, sap, bamboo, honey, bark, leaves, fruit, seeds, agarwood, energy-producing plants, and other food crops.
3	Area utilization	Cultivation and utilization of medicinal plants, ornamental plants, mushrooms, honey bees, wildlife protection, agroforestry, silvo-pasture, silvo-fishery, and agro-silvo-pasture.
4	Utilization of environmental services	Ecotourism, water management services, carbon sequestration and storage, and other environmental services

allowed to plant seasonal crops using land under the stands in the previous SF scheme in Java, the laws and regulations above would have made the community more flexible in managing the area according to local potential. Several potentials that can be developed by the community in full and already have a legal umbrella can be seen in Table 4.

All potential utilizations have been regulated in regulations that allow the community to be more flexible in SF activities. These activities can be carried out either partially or several simultaneously in the same permit. In addition to the potential for area development, multi-forestry business activities in KHDPK also open up opportunities for cooperation with wider business entities, such as cooperatives. Even SF management permits in KHDPK can be obtained directly by cooperatives, with certain requirements. This condition opens up opportunities for the growth of multi-forestry businesses in KHDPK.

D.2.Socio-economic and environmental factors

KHDPK opens up greater opportunities in developing environmental service products and HHBK based on local potential (Table 5). Potential can be a supporting factor, especially in increasing community income. Based on field observation, several potentials can be developed at the research location (Table 5).

Table 5. Potential non-timber forest products and environmental services

Village	Potential of NTFPs	Potential of environmental services
Golat	Coffee, sugar palm, rattan, and latex	Nature tourism (pine-based), clean water supplier, carbon absorption, carbon absorption
Bangunjaya	Coffee, honey, sugar palm, bamboo, and rattan	Nature tourism (waterfalls), carbon absorption
Bangunkarya	Durian, bamboo	Cisangkal nature tourism (landscape view), durian village tourism, clean water supplier, carbon absorption

Village	Potential of NTFPs	Potential of environmental services
Pangkalan	Sugar palm, bamboo, coffee, and durian	Nature tourism (waterfalls), clean water supply, carbon absorption
Jadikarya	Durian, bamboo	Durian village tourism, landscape view, carbon absorption

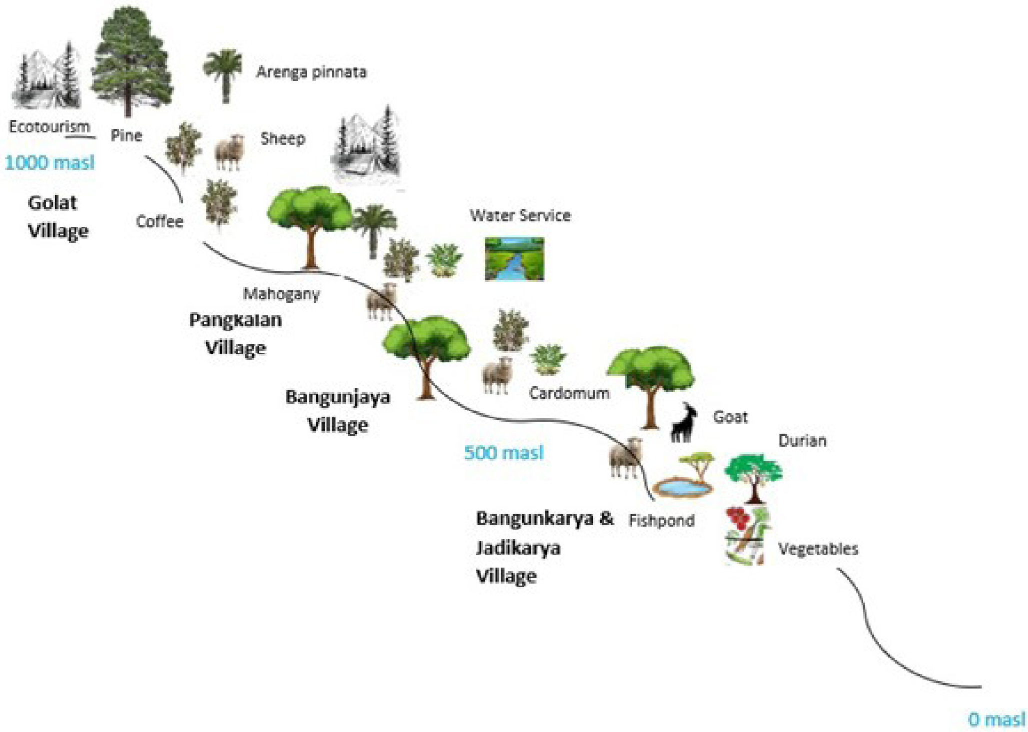

Figure 3. Overview of the multi-business forestry development model based on regional potential

The combination of supporting laws and regulations with the potential of each village is a very important enabling factor in the development of multi-business forestry. Based on the results of Table 4 and Table 5, a multi-business forestry development model can be prepared based on regional potential with an agroforestry pattern for each village in the social forestry scheme in KHDPK, as shown in Figure 3.

The image above shows that the higher a place is, the different types of commodities developed by the community. In lowland areas, people can develop product-based Mb-F, for example, of various animals and plants. While in the highlands, the types of commodities that can be created can be services, especially nature tourism and water sources. Open forest development has two sides that are sometimes contradictory. On the one hand, it can drive the community's economy.

On the other hand, if not supervised, it can cause environmental degradation. The community's tendency to optimise land productivity makes them more likely to prefer seasonal plants that produce quickly. Mb-F anticipates this by offering more flexible commodities without eliminating the ecological function of a forest area.

The effects of Indonesia's social forestry and forestry decentralization initiatives have been uneven. A lack of community involvement has resulted in decreased public welfare and damage to forest ecosystems, even though it has boosted regional autonomy (Pambudi, 2023; Tolo, 2014). Rapid policy changes and intricate bureaucratic processes have made it difficult to implement, for example, the Timber Legality Verification Certification (SVLK) policy, which was created to address concerns about unlawful logging (Suryandari et al., 2017). This situation has had a detrimental effect on community forest farmers and micro-industries, endangering the long-term viability of both community forests and the timber sector. To combat illicit logging and enhance wood output and forest management, Indonesia and the UK collaborated on the Multistakeholder Forestry Programme 3 (MFP 3) (Ridho et al., 2019). Stronger institutional support, more community capacity, and better laws are required to strengthen the efficacy of these programs (Pambudi, 2023; Suryandari et al., 2017).

IV. CONCLUSION

The synthesis of research on social forestry (SF) highlights its multifaceted benefits, including conflict resolution, sustainable resource management, financial feasibility, and land suitability. By integrating ecological, economic, and social considerations, SF emerges as a holistic approach to forestry management that addresses the complex challenges of balancing environmental conservation with socio-economic development. Multi-business forestry (Mb-F/MUK) was implemented before the Forest Area with Special Management (KHDPK) policy was inaugurated in 2022. The results of the Mb-F evaluation of SF activities in KHDPK show that the selection of species preferred and accepted by the community is closely related to economic value, as evidenced by five multi-business patterns that are most widely practised by the community, all of which are financially feasible. All multi-business patterns have a positive Net Present Value (NPV), Benefit-Cost Ratio (B/C Ratio) > 1, and Internal Rate of Return (IRR) greater than Bank Indonesia's benchmark interest rate. The main types of community choices, especially fruit types, are not all ecologically appropriate. The community continues to maintain this plant because it contributes highly economically. In addition, the kinds of NTFPs, especially those from the fruit category, also have ecological functions: water regulators, carbon storage, and other tree functions. The government can encourage the implementation of Mb-F on lands that are in conflict by offering wider access to land use. The Mb-F concept can also be adopted on critical lands, although intensive assistance and treatment must be carried out.

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AUTHOR CONTRIBUTIONS

AW: Data Collection, Writing Original Draft; DRN: Supervision, Writing Final Draft; ST: Supervision; SB: Supervision

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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IDENTIFICATION AND MAPPING OF DUSUNG SYSTEM AS LOCAL CULTURE-BASED AGROFORESTRY IN AMBON CITY, MALUKU PROVINCE, INDONESIA

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IDENTIFICATION AND MAPPING OF DUSUNG SYSTEM AS LOCAL CULTURE-BASED AGROFORESTRY IN AMBON CITY, MALUKU PROVINCE, INDONESIA. *Dusung*, the cultural heritage of Maluku, is a unique traditional agroforestry system. Formed from shifting cultivation and patrilineal land ownership, *dusung* has adapted to the environment of small islands. *Dusung* agroforestry is an effective solution to various environmental problems in watersheds, as it has been proven to maintain soil fertility, regulate water flow, prevent erosion, increase farmers' income, and preserve biodiversity. However, so far data and information about the species, structure, composition, and distribution of *dusung* agroforestry in watershed areas are still limited. This research aims to identify and map the distribution pattern of *dusung* agroforestry based on local wisdom in the Wai Batu Gajah Watershed, Ambon City. The methods used in this study include surveys and field observations. Structured interviews with 30 *dusung* farmers were conducted to explore local knowledge and *dusung* management practices. Vegetation analysis was carried out to determine the dominant species and species diversity. Furthermore, spatial analysis was applied to visualize and analyze the distribution pattern of *dusung* in more detail. The results show that *the dusung* agroforestry system has a medium plant species diversity, with the dominance of durian (*Durio zibetinus*), gandaria (*Bouea macrophylla*), mangosteen (*Garcinia mangostana*), kecapi (*Sondoricum koetjape*), langsat (*Lancium domesticum*), aren palm (*Arenga pinnata*), and salak (*Salacca zalacca*). The mapping of *dusung* distribution patterns underscores the importance of local culture in the dusung system's natural resource management. Study of 25 *dusung* based on *dati* (land ownership), the central role of customary institutions in maintaining this system's sustainability is clearly seen. These findings imply the need for further research to comprehensively analyze the economic, ecological, and social impacts of the sustainability of *dusung* agroforestry through the integration of local culture.

Keywords: Traditional forest farming, biodiversity, conservation, local wisdom, small island

IDENTIFIKASI DAN PEMETAAN SISTEM DUSUNG SEBAGAI AGROFORESTRI BERBASIS BUDAYA LOKAL DI KOTA AMBON, PROVINSI MALUKU, INDONESIA. Dusung, warisan budaya Maluku, adalah sistem agroforestri tradisional yang unik. Terbentuk dari sistem lahan berpindah dan kepemilikan lahan patrilineal, dusung telah beradaptasi dengan lingkungan pulau kecil. Agroforestri dusung adalah solusi yang efektif untuk berbagai permasalahan lingkungan di daerah aliran sungai (DAS), karena terbukti mampu menjaga kesuburan tanah, mengatur aliran air, mencegah erosi, meningkatkan pendapatan petani, dan melestarikan keanekaragaman hayati. Namun permasalahannya data dan informasi mengenai jenis tanaman, struktur, komposisi dan sebaran agroforestri dusung pada kawasan DAS masih belum tersedia. Penelitian ini bertujuan untuk mengidentifikasi dan memetakan pola sebaran agroforestri dusung berbasis kearifan lokal di DAS Wai Batu Gajah, Kota Ambon. Metode yang digunakan dalam penelitian ini meliputi survei dan observasi lapangan. Wawancara terstruktur dengan 30 petani dusung dilakukan untuk menggali pengetahuan lokal dan praktik pengelolaan dusung. Analisis vegetasi dilakukan untuk menentukan jenis vegetasi dominan dan keanekaragaman spesies. Selanjutnya, analisis spasial diterapkan untuk memvisualisasikan dan menganalisis

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pola sebaran dusung secara lebih rinci. Hasil penelitian menunjukkan bahwa sistem agroforestri dusung memiliki nilai keanekaragaman spesies yang tergolong sedang, dengan dominasi durian (Durio zibetinus), gandaria (Bouea macrophylla), manggis (Garcinia mangostana), kecapi (Sondoricum koetjape), langsat (Lancium domesticum), aren palm (Arenga pinnata), dan salak (Salacca zalacca). Pemetaan pola sebaran dusung menggarisbawahi pentingnya kearifan lokal dalam pengelolaan sumber daya alam dalam sistem dusung. Hasil kajian terhadap 25 dusung yang berlandaskan pada kepemilikan lahan dati, terlihat jelas peran sentral kelembagaan adat dalam menjaga keberlanjutan sistem ini. Temuan ini mengimplikasikan perlunya penelitian lebih lanjut untuk menganalisis secara komprehensif potensi ekonomi, dampak ekologi, dan dampak sosial dari keberlanjutan agroforestri dusung melalui integrasi kearifan lokal.

Kata kunci: Kearifan lokal, keanekaragaman hayati, konservasi, pertanian hutan tradisional, pulau kecil

I. INTRODUCTION

Environmental degradation in various parts of the world, especially in watersheds, has become a global issue that requires immediate attention and action. One of the most pressing challenges in this context is climate change, which significantly impacts various aspects of life, including the availability and competition of natural resources. As the main resource providers of life on land, watersheds become the conflict arena between human needs and environmental sustainability. In many cases, human activities often ignore sustainability principles, resulting in ecosystem damage, pollution, and soil quality deterioration (Guerra et al., 2020; Li et al., 2023).

The impact of climate change is especially happen on small islands, where watersheds play a crucial role in sustaining people's lives. Small islands, with unique watershed ecosystem characteristics, have limited resources and carrying capacity, making them the most vulnerable to climate change. This is due to its isolated geographical conditions, large coastal areas, and low economic diversification (Vrontisi et al., 2022). The impact of climate change on watersheds on small islands needs concern, as watersheds play an important role in all aspects of ecosystems, including clean water provision, local climate regulation, and support for biodiversity (Pristianto & Butudoka, 2023). These impacts are diverse, ranging from rising sea strata and coastal erosion to changes in rainfall patterns and increased frequency of disasters from weather impacts. This affects the quality and quantity of water, agricultural yields, food security, and surface water systems (Nagireddy et al., 2023). Therefore, sustainable management of natural resources in watersheds on small islands is crucial and requires more intensive conservation, mitigation, and adaptation efforts.

The Wai Batu Gajah Watershed, as a representation of the Ambon Island ecosystem, plays a crucial role in maintaining environmental balance, supporting the community's economy, and preserving its cultural values. As one of the water source for Ambon City, the Wai Batu Gajah Watershed is currently facing various environmental challenges. The narrow watershed area, coupled with steep topography, makes it vulnerable to disasters such as floods, landslides, and sedimentation (Talakua & Osok, 2017; Manakane et al., 2023). In addition, the decrease in land cover and the increase in residential areas are increasingly threatening the sustainability of this watershed. An adaptive, sustainable, and integrated land use management of the watershed is needed to minimize negative environmental impacts and overcome these challenges. One approach that can be applied is an agroforestry system.

An agroforestry system is a future land use solution and offers many benefits for the sustainability of natural resources and the environment (Prabawani et al., 2024). Agroforestry landscape is a sustainable land use system that maintains or increases total crop yields by combining food crops (annual) with tree crops (perennial) or livestock on the same land unit either simultaneously or alternately and managing it according to the ecological, economic, social and cultural characteristics of the local community (Vergara, 1982). In various parts of the world, agroforestry systems have been shown to improve farmers' welfare (Sulistiyowati et al., 2023), increase soil fertility (Octavia et al., 2023; Muchane et al., 2020), regulate water systems (Zomer et al., 2023), conserve biodiversity (Salt & Freudenberger, 2009; Octavia et al., 2022), increase food security (Octavia et al., 2024), mitigate climate change (van Noordwijk et al., 2021), and overcoming land degradation (Leakey, 2020).

In Indonesia, the concept of agroforestry has been applied in various forms. In Maluku, this system is uniquely known as *dusung*, which is a cultural heritage left by ancestors to their descendants, in the form of woody plants (trees), fruit plants, sago plants, palm plants, spice plants, or medicinal plants (Hatulesila, 2022). *Dusung* is the transformation from shifting cultivation practice towards permanent tree crop cultivation with patrilineal land ownership. *Dusung* is an intangible asset that includes indigenous knowledge and indigenous technology. It has norms and rules, embodied in *Sasi* and *Kewang*, which are customary institutions that maintain the sustainability of ecological and cultural systems on small islands (Ririhena, 2015). According to Girsang et al. (2023), the *dusung* ecological system generally consists of five subsystems: *Ewang* (forest), *A'ong (dusung)*, *'K'abong* (food and vegetable crops), *Kintal* (home garden), and coastal.

Dusung, as a form of traditional agroforestry and local community wisdom, is one alternative development model with the potential to serve as a soil and water conservation pattern to address problems in the Wai Batu Gajah Watershed. This is consistent with the findings of Asdak et al. (2023), who emphasize the importance of maintaining and promoting local wisdom in water resource conservation management within the framework of national policy, given that each region has unique characteristics in treating its environment sustainably. *Dusung* management by maintaining a minimum of 30% forest in land use in the watershed can produce a river discharge of 75.66 liters/second or 6537.02 m^3/day. This figure shows a significant increase compared to the condition of *dusung* management without maintaining forests in land use, where the resulting river discharge is only 1,412.16 mm or equivalent to 1.41m^3/second (Jacob, 2018).

The concept of *dusung* as a traditional agroforestry system, intended as a conservative agricultural pattern in the watershed area, is very promising, but its management is not optimal. This is because detailed information on its diversity, structures, the composition of *dusung* plants, and the distribution of *dusung* patterns in watershed areas based on local culture is still unavailable. In addition, *dusung* is still a subject of debate, primarily related to the complex relationship between land ownership rights (institutional), ecological, social, and cultural.

Several studies on agroforestry in global watershed areas have been conducted, but have focused only on conservative agricultural systems in addressing erosion, climate change, food crises, and economic value. Meanwhile, this study focuses on the study of *dusung* as a traditional agroforestry in the small island watershed area by identifying the species, composition, and structure of *dusung* agroforestry and mapping the distribution of *dusung* patterns based on local culture, which includes land ownership and customary institutions that help regulate the sustainability of *dusung* agroforestry. This research also seeks to see local communities' perceptions towards *dusung* agroforestry, how the community maintains *dusung*, and how the *dusung* pattern is formed in the community.

II. MATERIALS AND METHODS

This research has been approved by the Research Ethics Commission Involving Human Subjects of Bogor Agricultural University with the issuance of a Certificate of Passing the Ethical Assessment Number: 1420/IT3. KEPMSM-IPB/SK/2024 on August 28, 2024.

A. Location and time of research

The research was carried out in the *dusung* agroforestry area, Wai Batu Gajah Watershed, Sirimau District, Ambon City (Figure 1). The research took place from September to November 2024. The analysis was carried out at the Land Management Laboratory, Faculty of Agriculture, Pattimura University Ambon.

The Wai Batu Gajah Watershed has a catchment area of approximately 641.87 ha with a river length of 3,100 m (BPDAS 2019). The Watershed is located between the coordinates of 3°43'25"- 3°41'49"S and 128°12'22"-128°10'34"E. Administratively, the watershed covers several sub-district areas. In the upstream part are *Negeri* Soya, *Negeri* Hatalai, and *Negeri* Urimessing. Meanwhile, in the central part, there are urban villages of Batu Gajah and Batu Meja, and in the downstream, there are urban villages of Urimessing, Ahusen, Honipopu, Waihaong, Silale, and Uritetu.

The entire Wai Batu Gajah Watershed resembles a fan, with tributaries flowing into the main river from both the left and right sides. The tributaries flow concentrated to one point in the *Negeri* Soya. Based on the Oldeman classification system (1975), the Wai Batu Gajah Watershed is a climate type A1, classified as a very wet area, with tropical rainforests having >9 wet months and <2 dry months.

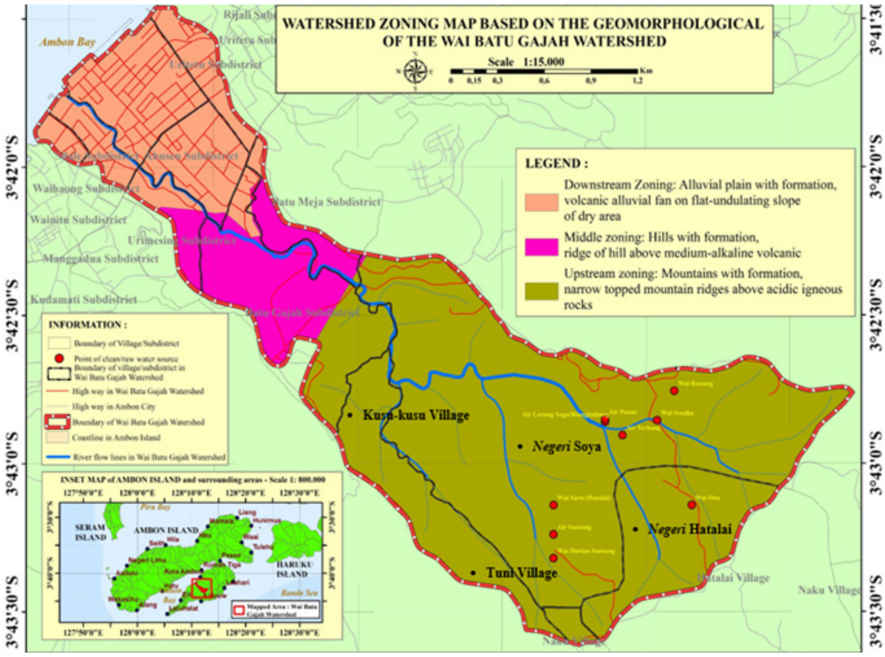

Figure 1. Research location map

Table 1. Area in the upstream of the Wai Batu Gajah Watershed

No	Region	District	Area (ha)	%	Number of Dusung (land ownership)
1	Negeri Soya	Sirimau	301,87	72	14
2	Negeri Hatalai	South Leitimur	64,67	15	5
3	Negeri Urimessing: Tuni Village	Nusaniwe	36,65	9	2
4	Negeri Urimessing: Kusu-kusu Village	Nusaniwe	18,33	4	4
		Total	421,52	100	25

This research was carried out with a focus on the upstream area of the watershed, where secondary dryland forests, known as *dusung*, are the dominant land use, covering 300.9 ha, or 46.88% of the total watershed area. Administratively, the upstream of the Wai Batu Gajah Watershed consists of three negeri (region), namely Soya, Hatalai, and Urimessing. Negeri Urimessing consists of four villages, two of which are located within the watershed area: Tuni Village and Kusu-kusu Village (Table 1). Ambon City still adheres to the government system of negeri. The term *negeri* refers to a village or region. Negeri is a communion of indigenous peoples, both genealogically and territorially, based on customs and culture (Ririhena, 2015).

B. Methods

1. Tools and materials

The equipment used in this study was Global Positioning System (GPS), roller meters, raffia ropes, machetes, computers with ArcGIS software, Avenza Maps application, Microsoft Office and Microsoft Excel, and cameras. The materials used were land unit maps (fieldwork maps), questionnaires, and plant identification books.

2. Types and collection of data

The study employed both primary and secondary data. Primary data included physical environmental data such as soil characteristics, topography, slope, land use, and plant species, while secondary data includes rainfall data and maps.

Primary data collection was carried out using transects and quadrat methods, while socio-cultural data collection used structured interviews with 30 sample participants. The participant sample selection technique was purposive sampling, with criteria including: (1) being the owner of the dusung, (2) aged 35-70 years, (3) active in the dusung, (4) having a clear land ownership status. Secondary data collection was carried out by visiting related agencies and collecting data: 1) Wai Batu Gajah Watershed Boundary Map; 2) Ambon Island Demnas Map; 3) Geological Map of Ambon Sheet; 4) Land Classification Map of Ambon City; 5) Indonesian Base Map of Ambon Sheet; 6) Bing Map Satellite Image Map and ESRI ArcGIS Imagery of Ambon City; 7) Image of SPOT 7 2024 - Ambon City; 8) Ambon City Regional Spatial Plan Map; 9) Geomorphological Map of Ambon Island Watershed; 10) Bulk and Agroclimatological Data of Ambon City in 2013-2023.

3. Participant characteristics

The selection of participants was carried out deliberately among farmers with the following criteria: a) having status as *dusung* owners; b) having more activities in *dusung*; c) having more than one *dusung*; d) having diverse plant species in *dusung*; e) the primary source of income is from crops in *dusung*. The selected sample of participants in the upstream area of the Wai Batu Gajah Watershed comprised 30 farmers aged 40-76 years. The basis for determining participants in this study followed the Central Limit Theorem, which states that 30 samples are the minimum required to approximate a normal distribution. This theory is supported by Thomson's (2010) statement that to obtain more in-depth data with a strong foundation, the number of participants can be increased to 30. Thus, researchers can identify more complex patterns, concepts, and dimensions.

Participants came from three *negeri*. There were 15 participants from *Negeri* Soya, 10 participants from *Negeri* Urimessing, and 5 participants from the *Negeri* Hatalai. Most participants had the latest strata of education in elementary, junior high, and higher education.

C. Analysis

1. Delineation of land units and transects

The delineation of land units was carried out based on the integration or overlay of several maps using ArcGIS, and then the land unit map output would be used as a fieldwork map. The overlay maps were land-use maps from the interpretation of ESRI

ArcGIS Imagery of Ambon City; Geological Maps of Maluku Province; Demnas Maps of Ambon Island; Land Classification Maps of Ambon Island; Terrain Maps; Maps of the Wai Batu Gajah Watershed; and Raw Water Resources Maps. After the land unit map was obtained, transect line plots were prepared for each *negeri* and village based on it. The use of transect lines allows researchers to capture spatial variation in vegetation composition and environmental conditions along elevation gradients, which is particularly important given the diverse topography of the watershed (Li, 2023). Transect lines were established in each *negeri*, starting from a point along the river and moving uphill to hilly areas. This transect line method is in line with the work of Iqbal et al. (2023), who described the delineation of transects derived from river morphology, taken from the midpoint of the river that extends to different upstream and downstream areas, thus providing a basis for understanding ecological interactions on elevation gradients. In total, 4 transect lines were established, with 1 (one) transect each in each *negeri* and village.

2. **Vegetation analysis in the *dusung* agroforestry system**

Vegetation analysis was carried out to see the species, structure, and composition of *dusung* agroforestry plants and determine the dominant species. The determination of dominant vegetation was carried out by calculating the Summed Dominance Ratio (SDR), which was a value that described the ability of a specific type of vegetation to control the existing mean of growth, and then calculating the Important Value Index (IVI), which was a value that showed the role of a plant species in the community (Mueller, 1974). In each of the selected *dusung* agroforestry transect routes, research plots were made using the quadrant plot method with sizes of 20x20m for tree, 10x10m for pole, 5x5m for sapling, and 2x2m for seedling (Figure 2). The number of replications in each plot was adjusted to the area and the number of *dusung* in each *negeri* (Table 1). This study grouped measurements into plants stages of seedling, sapling, pole, and tree based on the height and diameter of the stem. With this method, the researcher aims to obtain accurate and representative data regarding plant species diversity in each *dusung*.

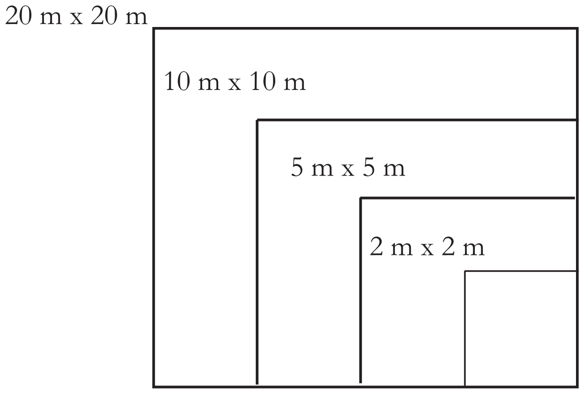

Figure 2. Plot form of quadrant plot sampling (Gondard, 2006)

Vegetation data obtained in the field is then analyzed by calculating:

a) The density, frequency, dominance, and IVI of plant species in *dusung* agroforestry studied based on Cox (1985) and SDR based on Janiya and Moody (1989) are as follows:

$$\text{Density (D)}= \frac{\text{Number of individuals}}{\text{Area of the sample}} \quad (1)$$

$$\text{Relative Density (RD)}= \frac{\text{Density of a type}}{\text{Density of all types}} \times 100 \quad (2)$$

$$\text{Frequency (F)}= \frac{\text{Number of tiles found in a type}}{\text{number of all sample tiles}} \quad (3)$$

$$\text{Relative Frequency (RF)}= \frac{\text{Frequency of a type}}{\text{Frequency of all types}} \times 100 \quad (4)$$

$$\text{Dominance (D)}= \frac{\text{The Basic area of a type}}{\text{Location of sample plot}} \quad (5)$$

$$\text{Relative Dominance (RD)}= \frac{\text{Dominance of a type}}{\text{Dominanceof all types}} \times 100 \quad (6)$$

$$\text{IVI for trees and poles}= \text{RD} + \text{RF} + \text{RD} \quad (7)$$

$$\text{IVI for saplings and seedlings}= \text{RD} + \text{RF} \quad (8)$$

$$\text{SDR for trees and poles}= \frac{\text{IVI}}{3} \quad (9)$$

$$\text{SDR for saplings and seelings}= \frac{\text{IVI}}{3} \quad (10)$$

3. **Analysis of plant species diversity**

The diversity of vegetation was determined using Shannon-Wiener index analysis of each quadrat sample along each transect line. Species diversity is calculated by the Shannon index formula (H') (Ludwig and Reynolds 1988) as follows:

$$H' = -\sum_{i-1}^{n} \left(\frac{n_i}{N}\right) \ln \left(\frac{n_i}{N}\right)$$

Information:
ni : Number of species
N : Total of all species
H' : Shannon-Wiener diversity index

The value of Shannon-Wiener species diversity (H') indicates the stability and complexity of a community. Odum (1993) classified the categories of the Shannon-Wiener (H') diversity index into three categories: H' > 3 (high), 1 ≤ H' ≤ 3 (medium), dan H' < 1 (low).

4. Mapping the distribution pattern of dusung agroforestry based on local culture

The distribution pattern of *dusung* agroforestry was mapped using a qualitative method with participatory observation through interviews with 30 *dusung* owners, a review of questionnaires, and field ground checks to obtain coordinate points for several *dusung* land holdings. After obtaining coordinate points, information on the use of *dusung*, socio-cultural values, limitations on *dusung* ownership, and dusung management in local culture, then the digitization process was carried out in two stages: 1) manual digitization (sketch) on the map sheet of land units on a scale of 1: 15:000, carried out with a Focus Discussion Group (FGD) approach between key informants: they were 4 *dusung owners*, 1 *Kewang*, and 2 *negeri* apparatus. *Kewang* (customary police) is a customary institution that functions to protect the land as a customary right of *negeri* in the land area; 2) after the *dusung* sketch was obtained, it was spatially poured using ArcGIS software based on the coordinate points that had been taken previously. The stages in the GIS analysis process consisted of the data input, processing, analysis, and result or output stages. The output of the GIS analysis was a map of the distribution of *dusung* agroforestry with a scale of 1: 15,000.

III. RESULT AND DISCUSSION

A. Identification of species, composition, and structure of agroforestry plant in the Wai Batu Gajah Watershed, Ambon City

Dusung agroforestry in the Wai Batu Gajah Watershed area is mostly used for producing agricultural and forestry products (Hairiah et al., 2003). The species of dusung plants are very diverse, ranging from long-lived plants (perennial) and short-lived plants (annual) with a mixture random planting patterns (Figure 3). This planting pattern is characterized by irregular planting of trees (not following runs or paths between food crops). This form is often found in traditional agriculture, where trees grow from natural regeneration and not through direct cultivation (Sahureka et al., 2024).

The species of dusung agroforestry found at the research site consisted of forestry plants such as: gomu (*Artocarpus communis*), sago (*Metroxylon sago*), bamboo (*Bambusa sp.*), gayam (*Inocarpus edulis*), palm (*Arenga pinnata*), salawaku

(a) (b)

Figure 3. *Dusung* with a random mixture pattern: (a) View from inside the *dusung*, (b) View of the *dusung* canopy

(*Paraserianthes falcataria*), waru tree (*Hibiscus tiliaceus*), timber titi (*Gmelina moluccana*), katimaha (*Kleinhofia hospital*), ganitri wood (*Elaeocarpus saphaericus*), galoba (*Alpinia sp.*), timo wood (*Timoneus sericeus*), fir (*Casuarina equisitifolia*), linggua (*Pterocarpus indicus*), agarwood (*Aquilaria spp.*), and noni (*Morinda citrifolia*). Agricultural tree crops such as: coconut (*Cocos nucifera*), cloves (*Syzygium aromaticum*), nutmeg (*Myristica fragrans*), langsat (*Lancium domesticum*), gandaria (*Bouea macrophylla*), durian (*Durio zibetinus*), melinjo (*Gnetum gnemon*), cashew (*Anacardium occidentale*), jackfruit (*Artocarpus heterophyllus*), breadfruit (*Arthocarpus communis*), and kecapi (*Sandoricum koetjape*), while lower crops are banana (*Musa sp.*), pineapple (*Ananas comosus*), cassava (*Manihot esculenta*), taro (*Xanthosoma sagittifolium*), and galangal (*Alpinia galanga*).

B. Important Value Index and Summed Dominant Ratio of dominant plants

The Important Value Index (IVI) and Summed Dominant Ratio (SDR) are parameters used to express the stage of dominance of species in a plant community. The higher the IVI and SDR values of a species relative to other species, the higher the role or stage of mastery of the species in the community (Mueller, 1974).

1. IVI and SDR of *dusung* agroforestry plant in *Negeri* Soya

Negeri Soya dominates the Wai Batu Gajah Watershed upstream, with an area of 301.87 ha or 72% of its total area. Such a significant area indicates a considerable potential to support biodiversity in *dusung* agroforestry practices. Observations in *Negeri* Soya show differences in plant species dominance across growth stages. The tree stage are dominated by durian (*Durio zibethinus*), the pole stage by the kecapi (*Sondoricum koetjape*), the sapling stage by salak (*Salacca zalacca*), and the seedling stage are dominated by ferns (*Selaginella wildani*) (Figure 4). The dominance of fruit crops, especially durian and kecapi, in the stage of trees and pole is in line with the findings of Ririhena (2015) study, which shows that *dusung* farmers in Negeri Soya are more likely to cultivate fruit and spice crops because of their economic value.

Result of the interviews found that *dusung* farmers more focused on the economic value in selecting the crops they plant. This is because *dusung* agroforestry is the main source of

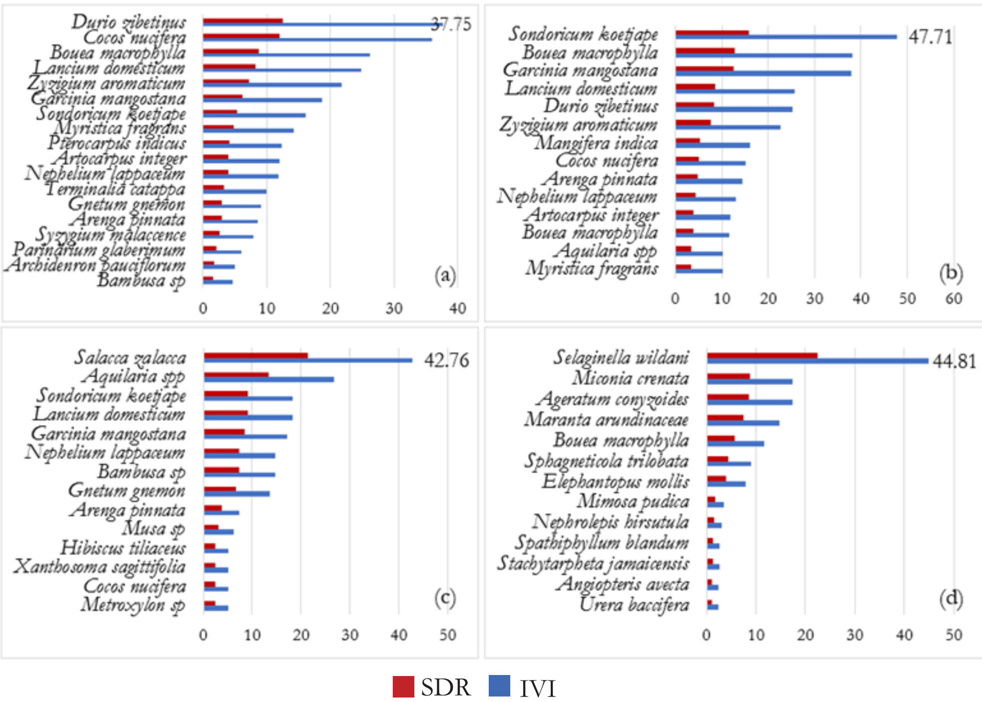

Figure 4. IVI and SDR of *dusung* agroforestry plant in *Negeri* Soya: (a) Treestage, (b) Pole stage, (c) Sapling stage, (d) Seedling stage

income for most households in the region, so farmers tend to choose crops with promising market potential. Agroforestry practices, as emphasized by Prastiyo et al., (2018), has been proven to increase crop production, which in turn ensures the stability and sustainability of farmers' income. In line with this, Maalalu (2020) also emphasized that the sustainability of hamlets is highly dependent on farmers' ability to meet their economic needs.

Other species of fruit plants that are cultivated by farmers and have economic value include gandaria (*Bouea macrophylla*), rambutan (*Nephelium lappaceum*), and langsat (*Lancium domesticum*). In addition, there are also spice plants species, such as cloves (*Zyzigium aromaticum*) and nutmeg (*Myristica fragrans*) commonly planted in *dusung*. Apart from its economic value, fruit plant species have an important ecological function as well for land conservation. This is in line with the findings of Prastiyo et al., (2020) which showed that about 38% of agroforestry plant species in the tree strata that dominate the growing area function as conservative plants in maintaining ecosystem stability, such as reducing sedimentation accumulation, preventing erosion, and as buffer plants on steep topography. One example of a local plant in Maluku that has a conservation function is kecapi (*Sondoricum koetjape*), whose deep root system can function for reforestation and rehabilitation of critical land (Ririhena, 2015). The results of the calculation of the dominant value of the species found that kecapi dominates the land cover in *Negeri* Soya, which is shown by its appearance in the stage of trees, poles, and saplings. Furthermore, seedling stage analysis shows the existence of 28 species of grass with a total of 395 individuals. The dominance of this grass species in the underlayer indicates its important role in preventing erosion, reducing run off, and maintaining soil fertility. In addition, dominant grass species such as *Selaginella wildani* and *Ageratum conyzoides* indicate the potential for further utilization as a source of biopharmaceuticals (Silalahi, 2019).

2. IVI and SDR of *dusung* agroforestry plant in *Negeri* Hatalai

Diversity of plant species in *Negeri* Hatalai is high in various growth stage. There are 17 species in the tree stage, 9 species in the pole stage, 10 species in the sapling stage, and 14 species in the seedling stage (Figure 5), with an

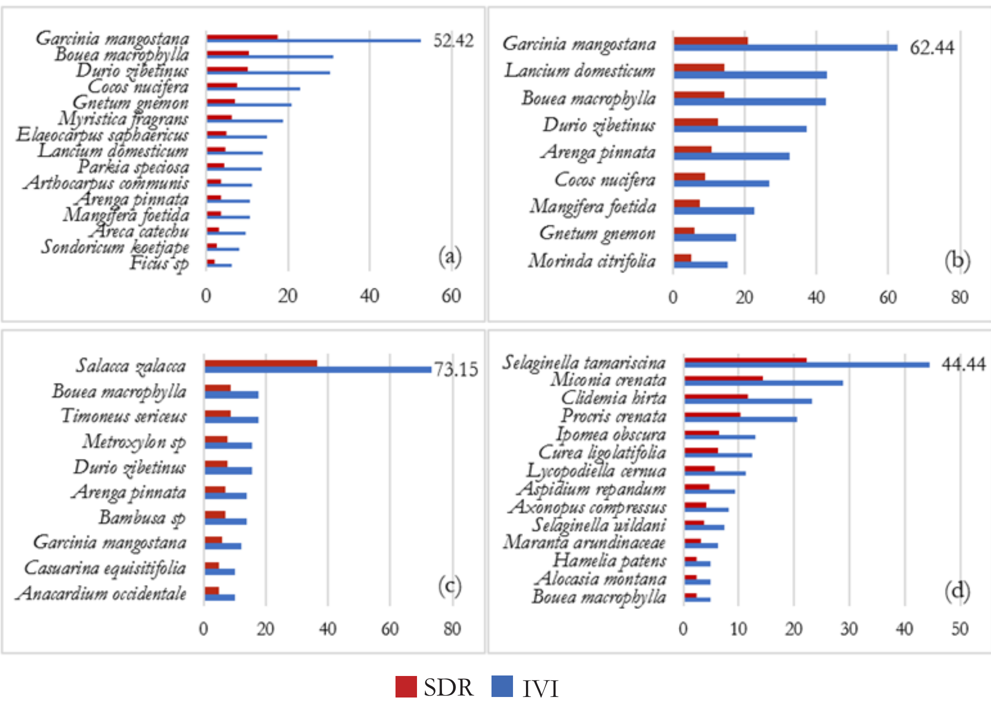

Figure 5. IVI and SDR of *dusung* agroforestry plant in *Negeri* Hatalai. (a) Tree stage, (b) Pole stage, (c) Sapling stage, (d) Seedling stage

area of 64.67 ha or 15% of the total upstream area of the watershed. The results of IVI and SDR calculations show that the plant species that dominate this area are fruit plants, namely mangosteen (*Garcinia mangostana*) in the tree and pole stage and salak (*Salacca zalacca*) in the sapling stage. Meanwhile, the seedling stage are dominated by fern grass, *Selaginella tamariscina*. The interview results indicate that mangosteen is the primary commodity cultivated by Hatalai Dusung farmers. Mangosteen, a heritage and well-adapted plant to the local environment, has significant economic value for the income of the farmer's family.

In addition to mangosteen, durian, gandaria, coconut, breadfruit, langsat, nutmeg, and salak are also important cultivated crops in this region. Moreover, the region is rich in biodiversity, including various species of forestry plants such as palm (*Arenga pinnata*), pine (*Casuarina equisitifolia*), ganitri wood (*Elaeocarpus saphaericus*), and gohi (*Ficus sp.*). The dominance of *Selaginella tamariscina* species is detected at the seedling stage, followed by *Miconia crenata*, *Clidemia hirta, Curea ligolatifolia,* and *Procris crenata*. The diversity of these grass species indicates great potential as a source of biopharmaceuticals (Silalahi, 2019; Youn, 2024) and plays a vital role in preserving soil. This aligns with a study by Moncada (2022), which states that grass species at the seedling stage can increase soil resistance to erosion. They achieve this by strengthening soil aggregates through dense root networks and root secretions that act as natural adhesives. In addition to erosion resistance, plants with a distinct structure and dense canopy arrangement buffer surface run-off, thereby increasing soil infiltration and groundwater capacity. This is particularly important for watersheds on small islands characterized by steep topography, which are sensitive to drought due to limited water resources and the threat of erosion, which can significantly affect water quality and quantity. Thus, diverse grass species at different stages of growth in watershed areas can improve soil stability and protect water resources on small islands (Silaya & Latupapua, 2024).

3. IVI and SDR of *dusung* agroforestry plant in Tuni Village

Tuni Village is part of the *Negeri* Urimessing, which covers 36.65 ha, or 9% of the watershed's upstream area. There are 20 plants species found at the tree stage, 12 species at the pole

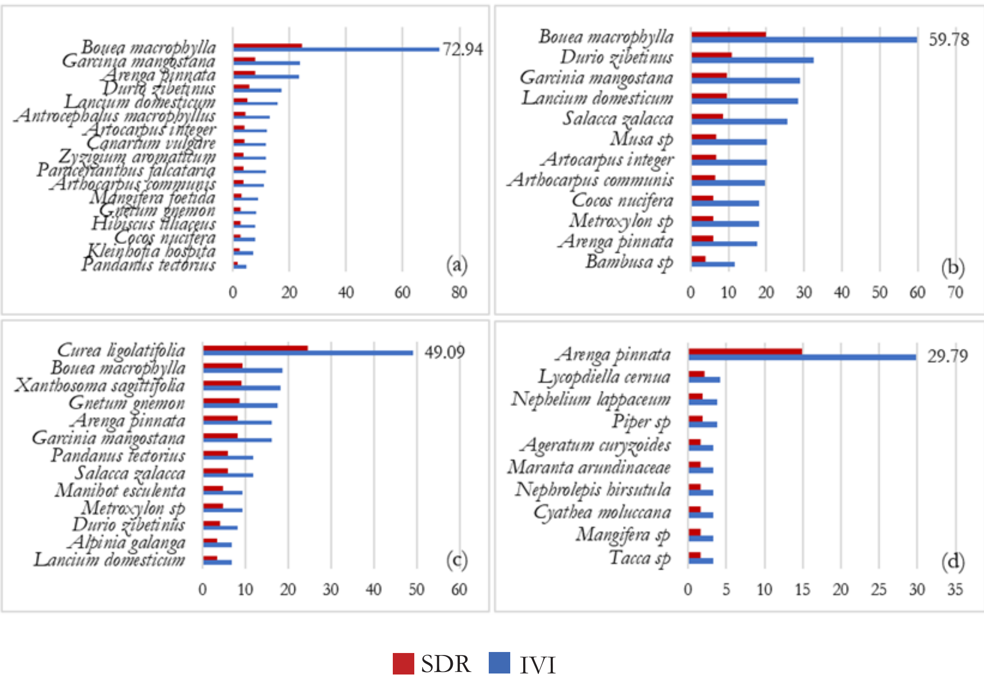

Figure 6. IVI and SDR of *dusung* agroforestry plant in Tuni Village. (a) Tree stage, (b) Pole stage, (c) Sapling stage, (d) Seedling stage

stage, 13 species at the sapling stage, and 25 species at the seedling stage. The results of IVI and SDR calculations found that the plant species that dominate *Dusung* Tuni are gandaria (*Bouea macrophylla*) at the tree and pole stage, kora-kora (*Curea ligolatifolia*) at the sapling stage and palm (*Arenga pinnata*) at the seedling stage (Figure 6). Gandaria dominates almost of all growth stage, and has the highest Important Value Index (IVI). In that case, gandaria shows high growth stability in the ecosystem than other species. Thus, the dominance of gandaria reflects its adaptability to the environment and its significant contribution to the diversity and balance of the surrounding ecosystem (Silaya & Latupapua, 2024).

Results of interviews with Tuni *Dusung* farmersrevealed that there is an interesting cultivation pattern. Although gandaria (*Garcinia mangostana*) dominates the ecosystem with high IVI values, local communities rely on palm plants (*Arenga pinnata*) as an important commodity. Palm sugar (*nira*) is processed into a traditional *sageru* drink, which has high socio-cultural value for the people in Maluku and is known as a symbol of *simplicity and togetherness* (Ririhena, 2015). Uniquely, the sugar palm has a long harvest cycle and stable economic value, making it a sustainable source of income for farmers. The economic potential of this palm plant is supported by various studies, including Azhar et al. (2022), which showed that farmers' total income in a year amounted to 15,600,000 IDR with an R/C value of 2.84, and a study by Titabano, Pattinama, and Thenu (2018) that showed the average farmers' income from production of palm sap for sageru was 3,099,284 IDR with a BCR value of *sageru* processing by 1.60. This indicates that the business of processing palm derivative products, such as palm sugar and *sageru*, has high economic feasibility.

4. IVI and SDR of *dusung* agroforestry plant in Kusu-kusu Village

Kusu-kusu Village, has an area of only 18.33 ha or 4% of the total upstream area of the Wai Batu Gajah Watershed. Even though it is the smallest area, Kusu-kusu Village also has a relatively high diversity of plant species. Observations indicate 11 species of trees, 6 species of poles, 11 species of saplings, and 8 species of seedlings. Despite having a relatively small area, Kusu-kusu Village contributes to the biodiversity in the upstream watershed area.

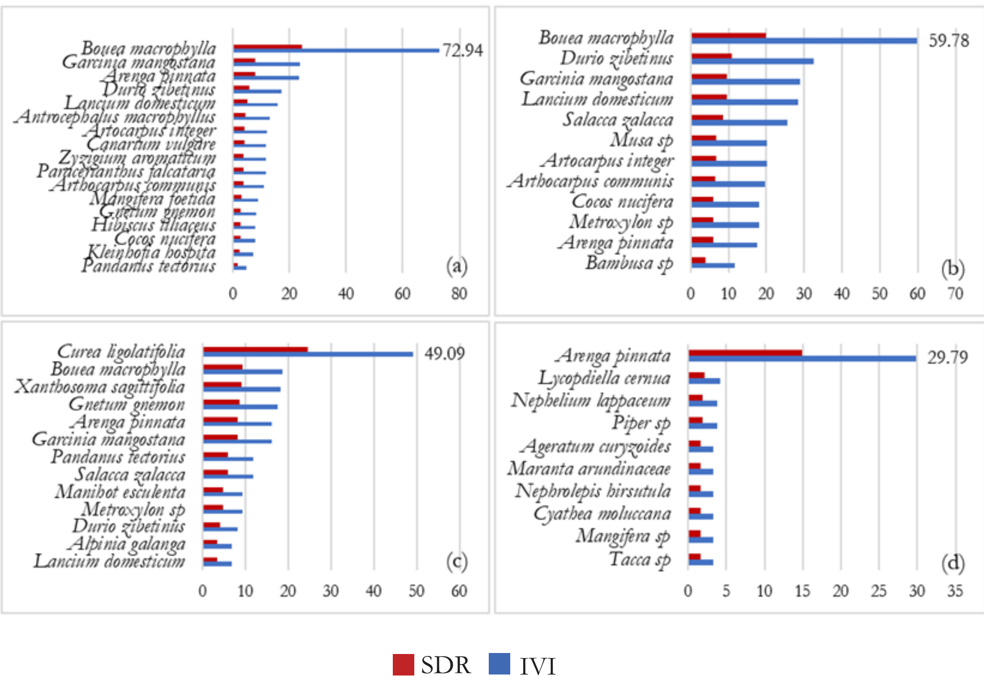

Figure 7. IVI and SDR of *dusung* agroforestry plant in Kusu-kusu Village. (a) Tree stage, (b) Pole stage, (c) Sapling stage, (d) Seedling stage

The results of IVI and SDR calculations show that fruit crops that dominate the area are durian (*Durio zibetinus*) at the tree stage, gandaria (*Bouea macrophylla*) at the pole stage, langsat (*Lancium domesticum*) at the sapling stage, and pakis merak (*Selaginella wildani*) at the seedling stage (Figure 7).

The results of the vegetation analysis in Kusu-kusu Village show a pattern similar to that of the other three villages, which have high diversity of plant species. The vegetation composition includes a wide range of species, from perennials to annuals. The structure of the dusung agroforestry canopy in this village is complex, with clear stratification and diverse root systems. This characteristic indicates that dusung agroforestry is a sustainable land management system, able to increase biodiversity (Salt & Freudenberger, 2009), increase carbon storage capacity (Filqisthi et al., 2017), and plays an important role in mitigating natural disasters such as erosion and landslides (van Noordwijk et al., 2021). In addition, this system also contributes to the preservation of soil fertility (Muchane et al., 2020; Octavia et al., 2023).

C. Species diversity index (H') of *dusung* agroforestry vegetation in the Wai Batu Gajah Watershed

Based on observations, it was found that the richness of plant species in the upstream part of the Wai Batu Gajah Watershed is relatively high, with 95 species of trees belonging to 35 families. The dominance of plant species in the *dusung* agroforestry in this region is shown by the Myrtaceae family, which includes species such as cloves, rose apple, malay apple, and guava, as well as the Arecaceae family, which includes palm, sago, salak, coconut, and areca nut. The plant diversity index obtained ranges from 1.93 to 2.42, indicating a medium stage of species diversity with a value of $1 \leq H' \leq 3$ (Odum, 1993) (Table 2). This medium Shannon-Wiener index value indicates that *dusung* agroforestry exhibits a fairly diverse number of species with relatively even species abundance. This diversity is reflected in the variety of species found in the *dusung* fields across each growth stratum within each *negeri*. Furthermore, the medium diversity index of *dusung* agroforestry suggests that the *dusung* ecosystem maintains considerable stability. This is supported by the research of

Table 2. Species diversity index at different growth stages

Negeri/Village	Growth rate	Total		Species diversity index (H')	Category
		Species	Individual		
Soya	Tree	19	118	2.58	Medium
	Pole	13	75	2.17	Medium
	Sapling	14	85	2.28	Medium
	Seedling	28	397	2.67	Medium
Hatalai	Tree	17	101	2.26	Medium
	Pole	8	43	1.95	Medium
	Sapling	10	54	1.77	Medium
	Seedling	14	159	2.20	Medium
Tuni	Tree	20	118	1.90	Medium
	Pole	12	60	2.06	Medium
	Sapling	13	79	2.10	Medium
	Seedling	25	216	2.53	Medium
Kusu-kusu	Tree	10	43	2.10	Medium
	Pole	6	18	1.61	Medium
	Sapling	11	26	2.20	Medium
	Seedling	8	55	1.83	Medium

Kaswanto and Nakagoshi (2014) and Prastiyo et al. (2020), which states that even with medium plant diversity in agroforestry within watershed areas, the overall ecosystem condition remains relatively balanced and ecological pressure is still controlled.

The medium species diversity index of *dusung* agroforestry is due to community consideration on the plant economic value. Previous study by Irwanto et al. (2023) and Markum et al. (2021) showed that there is a tendency for people to choose and plant the plants that have high economic value, such as multipurpose tree species (MPTS), in the hope of increasing income quickly. As a result, natural forest vegetation is often replaced by the dominance of cultivated plant species. However, each region has unique agroclimatic characteristics, so the leading agricultural commodities in each *negeri* and village varies. Therefore, the development of agricultural commodities needs to be adjusted to the characteristics of the local agroforestry landscape to improve community welfare (Kaswanto et al., 2021)

Negeri Soya has the highest value of species diversity in all growth stage. The lowest value of species diversity is in the *Negeri* Urimessing, Kusu-kusu Village at the stage of pole and seedlings. In contrast, at the sapling stage, a low diversity index is found in *Negeri* Hatalai. The low value of species diversity is due to the low number of individuals of the cultivated plant species. Considering that Ambon Island is a small island with limited land carrying capacity, it is important to increase the species diversity of *dusung* species to maintain the richness of biodiversity and protect the island from the threat of erosion and climate change.

Overall species diversity is highest at the tree level and decreases at the pole, sapling, and seedling levels. However, plant species diversity has increased and is categorized as very high at the seedling level in *Negeri* Soya, *Negeri* Hatalai, and Tuni Village. High species diversity values indicate that *dusung* system agroforestry practices can maintain biodiversity on small islands.

D. Distribution pattern of dusung agroforestry based on local culture in the Wai Batu Gajah Watershed

1. *Negeri* Government System

The study results show that *dusung* agroforestry is concentrated in the upstream part of the watershed, which covers 3 *negeri*, *Negeri* Soya, *Negeri* Urimessing, and *Negeri* Hatalai. Ambon City still adheres to the *negeri* government system, which refers to villages or regions. *Negeri* is a communion of indigenous peoples, both genealogically and territorially, based on customs and culture (Ririhena, 2015). *Negeri* is led by the *Bapa Raja*, who is elected based on the lineage of the King (*patriarchal*). In his reign, the King was assisted by customary institutions with precise functions in the structure of the *Negeri* government, namely *Raja/Pati, Saniri Besar*, and *Saniri Negeri*.

Saniri Besar is a customary forum at the *negeri* consisting of government apparatus *negeri*, jujaro (adult female), and mungare (adult male). This forum serves as a communication channel between the King, negeri government officials, and the community. *Saniri Negeri* is a customary institution at the *negeri* consisting of the *King, Kepala-kepala Soa, Marinyo, Kewang, Tuan Tanah*, and *Kapitang*. *Saniri Negeri* serves as a *Negeri* legislative institution that makes various decisions for the King and the people of *Negeri*. *Kepala Soa* is the leader of several negeri clan functions to assist the King in handling customary problems and various administrations of *negeri*. *Kepala Soa* also acts as a spokesperson for the clan he leads. *Kapitang* is a warlord in charge of coordinating the community when facing attacks from outside that threaten the internal security of *negeri*. In the Maluku cultural tradition, *Kapitang* is a title given to a leader or tribal chief who has an important role in regulating the community's life and maintaining the security of his territory. The primary duties of *Kapitang* include leading traditional ceremonies and resolving conflicts. *Tuan Tanah* has the power to regulate the rights of the land of the landowners. Its main task is to organize and solve problems with other *negeri*, such as determining land boundaries and petuanan (territorial) land disputes. *Kewang* (customary police) is a customary institution that safeguards petuanan as a customary right (*beschikkingrecht*) located inland areas and on the coast. *Marinyo* was tasked with helping the King to convey various information about the existence of *negeri*, conveying various decisions and programs taken by the King and *Saniri Negeri* to be implemented. *Marinyo* and *Kepala Soa* are the King's assistants in the field of administration.

2. Land ownership system and *dusung* agroforestry mapping in the Wai Batu Gajah Watershed

The land ownership system for *dusung* agroforestry in the research area is named *dati* or customary rights. The term *dati* has been used since the Dutch colonial era to the present. Hamlet or land *dati* have registered *dati* since 1814 in *Eigendom Verponding*, which is the right to land ownership that must be adjusted through the provisions of the conversion of the Basic Agrarian Law (*Undang-undang Pokok Agraria*/UUPA) (Pontoh et al., 2022). Land distribution of *dusung* based on land ownership in each *negeri* presented in Figure 8 and Table 3.

Based on the results, most of *dusung* agroforestry land ownership at *Negeri* Soya, Hatalai, and Urimessing are *dusung dati*. In addition, there are also *dusung negeri, dusung pusaka, dusung babalian* and *dusung atiting* on some land *dusung* at *Negeri* Soya. *Dusung dati, pusaka, atiting*, and *babalian* are *dusung* with customary ownership or genealogis. Traditionally, genealogical members have the right to manage or clear the land. This right consists of the right to the land owned by negeri or controlled by the genealogical (*matarumah* or family refers to the clan).

The results of interviews and FGDs show that all land ownership in the upstream part of the watershed is customary land, which was inherited from the elders (previous generations that can still be traced). *Dusung* agroforestry with a customary land ownership system, or dati, has a special name that has been given since the beginning of inheritance. The name *dusung* usually refers to the area or region where the *dusung* is located, such as the name of a place or source of a spring, and it is a special name in the indigenous language. Each *dusung dati* owned by several *matarumah* that have a genealogical or kinship relationship.

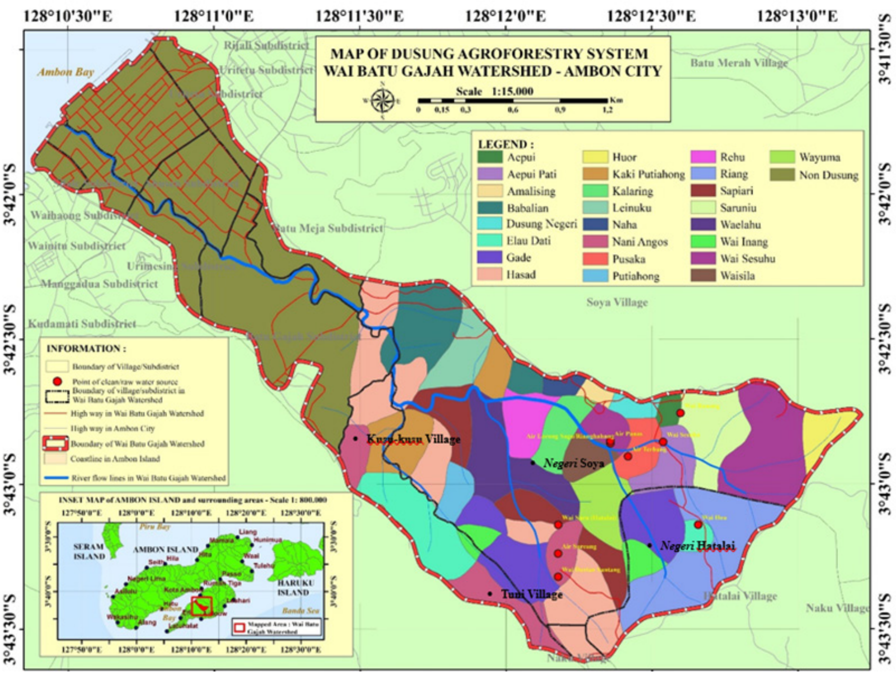

Figure 8. Distribution map of *dusung* agroforestry based on local culture

Table 3. Distribution of *dusung* land ownership in the Wai Batu Gajah Watershed

Negeri	***Dusung* name**	***Matarumah* (Households)**	**Types of dusung**
Negeri Soya	Babalian	Latuheru	*Babalian*
	Leinuku	Soplanit	*Dati*
	Naha	Nussy	*Dati*
	Babalian	Pessiwarisa	*Babalian*
	Waelahu	Rehatta	*Dati*
	Reru	Pattileuw	*Dati*
	Kalaring	Sopacua	*Dati*
	Amalising	Tamtelahitu	*Dati*
	Waisila	Maitimu	*Dati*
	Wayuma	Hijiaubessy	*Dati*
	Wai Sesuhu	Kebun Kelapa Soplanit	*Dati*
	Dusung Negeri	Kebun Kelapa *Negeri*	*Negeri*
	Aepui	Huwaa	*Dati*
	Pusaka	Sapteno, Soplanit, Salampessy	*Pusaka*
	Wai Sesuhu	Soplanit	*Dati*
	Huor	Soplanit	*Dati*
	Aepui Pati	Air Terbang Huaang	*Dati*
	Saruniu	Rehatta	*Dati*
Negeri Hatalai	Elau *Dati*	Puturuhu	*Dati*
	Gade	Muskita	*Dati*
	Riang	Paays	*Dati*
	Wai Inang	De Lima	*Dati*
	Riang	Kastanya	*Dati*
Negeri Urimessing	Hasad	Alfons	*Dati*
	Nani Angos	Huwae	*Dati*
	Kaki Putiahong	Persulessy	*Dati*
	Elau *Dati*	Puturuhu	*Dati*
	Putiahong	Parera	*Dati*
	Sapiari	Gomies	*Dati*

Remark: *Dati* (ownership of dusung based on *matarumah*/clan), *Babalian* (purchased *dusung* from negeri), *Pusaka* (*dusung* jointly owned by a group of heirs), *Negeri* (dusung owned by negeri).

The total amount of dusung agroforestry spread in the upstream part of the Wai Batu Gajah Watershed are 25 *dusung* consisting of 14 *dusung* of petuanan *Negeri* Soya, 5 *dusung* of petuanan *Negeri* Hatalai and 6 *dusung* of petuanan *Negeri* Urimessing. The most common type of *dusung* land ownership found in the upstream area of the Wai Batu Gajah Watershed is the ownership of *dati*. This is because *dusung* agroforestry lands are already under the ownership of family land that has been registered in the national register. Many *negeri*-owned *dusung* have also been sold to related families, so the ownership rights of *dusung* have changed. *Dusung* with *dati* ownership means that, in one *dati*, several families, such as *dusung* or *matarumah*, have been separated following the ownership of each family. Each family is responsible for its dusung, except for the *dusung pusaka*. *Dusung pusaka* is a *dusung* jointly owned by a group of heirs inherited from generation to generation and based on patrilineal principles. The group of heirs is a combination of several households or *matarumah*, and there is no general land division as in *dusung dati*. Conflicts often arise when managing and utilizing the yield in *dusung pusaka* because there are no clear rules about the distribution of inherited crops in *dusung pusaka*. The findings of this study are in line with Silaya & Pietersz's (2019) research, which states that conflicts often occur in *dusung pusaka* because each household group positions itself as the most interested party in the management of *dusung pusaka*.

3. *Sasi* and *Kewang* customary institutions

Agroforestry landscape practices of *dusung* are very important and strategic for the survival of the *dusung* owner and the environment. This is due to the close relationship between *dusung* and local culture. For example, the history of *dusung* area ownership, the practice of local culture (*Sasi*), and the existence of a local institution called *Kewang* (customary police) are believed to be able to control the preservation of resources of *dusung* (Ririhena, 2015; Silaya & Waistsz, 2019).

Sasi is a form of community-based natural resource management rules in Maluku. *Sasi* is a traditional culture that exist in customary regulations that prohibit the extraction of specific natural resources to conserve the quality and population of biological resources (Kissya, 1993). Customary regulations have become local rule for local communities that have been followed for generations and declared as a prohibition to maintain a resource's sustainability (Baguna et al., 2015). Meanwhile, *Kewang* is a customary institution that protects petuanan (land) as a customary right in the *negeri* inland and coastal areas. The research found that *sasi* customary law has experienced a decline in implementation and even disappeared from the culture of the community. For example, in *Negeri* Soya and Tuni Village, the community does not use *sasi* customary law in *dusung* cultivation. This indicates that: 1) *sasi* customary law in *dusung* cultivation was influenced by modernization, *Negeri* Soya is near the center of Ambon City, so that the socio-culture of the community is eroded; 2) the community is already responsible for their respective *dusung* products in management so that there is no theft of produce or crop failure; 3) *dusung* boundary conflicts rarely occur because of mutual understanding between the *dusung* owners regarding the boundaries of their respective land. This clear understanding has been built through social interaction and hereditary experience and is reinforced by local land use rules.

4. *Dusung* agroforestry cultivation system based on local culture

Agroforestry is an intangible asset in Ambon City, included among indigenous knowledge and technologies adapted to the island environment (Ririhena, 2015; Hatulesila, 2022). Therefore, *dusung* farmers at the research site have used traditional methods to manage *dusung* agroforestry land. This traditional approach is relevant to the concept of optimal indigenous land management, which integrates technical, economic, social, and ecological aspects to achieve forest landscape sustainability (Nugroho et al., 2017). The cultivation of *dusung* plants based on the local culture of the local community is carried out in the following stages: 1) land clearing (weeding), 2) land tillage, 3) making planting holes and leaving them open for 3 days, 4) making compost by burning dry plant litter, 5) putting compost (ash from burning) into the planting hole, 6) planting plant seedlings, 7) watering, 8) maintenance with weeding. Ash from combustion is traditionally understood to contain calcium, which neutralizes acidic soil.

The practice of *dusung* agroforestry cultivation carried out by farmers, in terms of local culture, is greatly influenced by the values of cooperation known as *masohi*. *Masohi* is a tangible manifestation of the spirit of community togetherness in collectively managing natural resources. This activity involves all community members in various stages of cultivation, from land clearing to harvesting. As Sahureka et al. (2018) emphasized, *masohi* is not just a physical activity but also a manifestation of the socio-cultural values of the Maluku people. Through *masohi*, the bond of brotherhood between families is getting closer, as seen in the *dusung* agroforestry production process, that involving all family members (Kroons et al., 2022; Hatulesila, 2022). In addition to strengthening social ties, *masohi* contributes to the efficiency of managing the *dusung* agroforestry because heavy tasks can be completed together. This saves costs and ensures the sustainability of the dusung agroforestry system (Tjoa et al., 2022).

IV. CONCLUSION

Dusung agroforestry in the Wai Batu Gajah Watershed area is the use of agrisilviculture land with a mixture-random pattern that has significant potential in improving the ecological, economic, and socio-cultural sustainability of the community. Vegetation analysis shows that there are 95 species of *dusung* agroforestry at the tree, pole, sapling, and seedling stages belonging to 35 families. The vegetation analysis shows that this system's species diversity is medium, with Shannon-Wiener index (H') ranging from 1.93 to 2.42. Vegetation that dominates *dusung* land with high INP and SDR values consists of fruit plants, namely durian (*Durio zibetinus*), gandaria (*Bouea macrophylla*), kecapi (*Sondoricum koetjape*), mangosteen (*Garcinia mangostana*), langsat (*Lancium domesticum*), aren palm (*Arenga pinnata*) and salak (*Salacca zalacca*). Meanwhile, grass species such as peacock fern (*Selaginella willdani*) and fan grass (*Selaginella tamariscina*). Based on the land ownership and the distribution pattern of *dusung* based on local culture, there are 25 dusung spread in the upstream watershed consisting of 14 *dusung* in *Negeri* Soya, 5 *dusung* in *Negeri* Hatalai, and 6 *dusung* in *Negeri* Urimessing. The traditional *dusung* agroforestry management is still heavily influenced by *sasi* customary law and *kewang* customary institutions. This system regulates using natural resources in dusung agroforestry to ensure environmental sustainability and community welfare.

Mapping the *dusung* agroforestry landscape patterns based on local culture reveals the close relationship between traditional agricultural practices and natural resource management. As an agroforestry system rooted in local culture, *dusung* establishes norms and rules that support ecological sustainability and sustain social systems that have been internalized in the community's lives.

This study recommends regular replanting of *dusung* vegetation to increase the biodiversity of *dusung* agroforestry. Improved management, such as optimal spacing and selection of superior commodities, is essential to increase species' productivity and richness. To strengthen the role of *sasi* and *kewang*, it is necessary to activate and empower *kewang*, a customary institution with the authority to supervise and enforce *sasi* implementation. In addition, a strategic step is to mandate *dusung* owners as environmental guardians, supported by clear reward mechanisms and incentives, so that *dusung* agroforestry is sustainable. Government support is needed through counseling, training, and assisting the *dusung* farmers in implementing sustainable agricultural practices (Good Agricultural Practices). With proper management, the *dusung* agroforestry system can become a sustainable agricultural model that not only increases farmers' productivity and income but also plays an important role in mitigating climate change, improving food security, and preserving the ecosystem of small islands. The results of this study imply the need for further research to comprehensively analyze the economic potential, ecological impacts, and social impacts of the sustainability of *dusung* agroforestry through the integration of local culture, in order to optimize the role of *dusung* in sustainable development in small islands.

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ORIENTATION OF STAKEHOLDERS ON THE ECOREGIONAL IDENTITY OF THE GAYO HIGHLANDS FOR ECOTOURISM DEVELOPMENT IN ACEH TENGAH DISTRICT, ACEH PROVINCE

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ORIENTATION OF STAKEHOLDERS ON THE ECOREGIONAL IDENTITY OF THE GAYO HIGHLANDS FOR ECOTOURISM DEVELOPMENT IN ACEH TENGAH DISTRICT, ACEH PROVINCE. The massive increase in efforts to develop ecotourism in Indonesia has made the concept of ecoregional identity necessary for strengthening the comparative advantage of inter-regional ecotourism development. This research was conducted to analyze, map, and interpret stakeholder orientation toward ecoregional identity for ecotourism development in the Gayo Highlands, Aceh Province, especially Aceh Tengah District. The study was conducted by analyzing the perceptions, motivations, and preferences of stakeholder groups; by adopting the One Score One Criteria Scoring System for 7 aspects: ecological, socio-cultural, socio-economic, social politics, development, regional, and ecotourism. The analysis showed that stakeholder orientations toward ecoregional identity for ecotourism development remained relatively low: of the 327 ecoregional identity types mapped, only 41% were recognized by stakeholders. The ecoregional identities that are trending and have significant economic value at this time are Gayo Coffee, Lut Tawar Lake, and Depik Fish, which have the highest stakeholder orientation in Aceh Tengah District. This fact not only weakens the functions of other ecoregional identities, which are also important for ecotourism development, but also causes the loss and even extinction of these identities.

Keywords: Concept, ecoregional identity, ecotourism, Gayo Highlands.

ORIENTASI PEMANGKU KEPENTINGAN TERHADAP IDENTITAS EKOREGIONAL DATARAN TINGGI GAYO UNTUK PENGEMBANGAN EKOWISATA DI KECAMATAN ACEH TENGAH, PROVINSI ACEH. Peningkatan besar-besaran upaya pengembangan ekowisata di Indonesia telah menjadikan konsep identitas ekoregional sebagai kebutuhan untuk memperkuat keunggulan komparatif pengembangan ekowisata antar wilayah. Penelitian ini dilakukan untuk menganalisis, memetakan, dan menginterpretasikan orientasi pemangku kepentingan terhadap identitas ekoregional untuk pengembangan ekowisata di Dataran Tinggi Gayo, Provinsi Aceh, khususnya di Kecamatan Aceh Tengah. Studi ini dilakukan dengan menganalisis persepsi, motivasi, dan preferensi kelompok pemangku kepentingan; dengan mengadopsi One Score One Criteria Scoring System untuk 7 aspek: ekologis, sosial-budaya, sosial-ekonomi, sosial politik, pembangunan, regional, dan ekowisata. Analisis menunjukkan bahwa orientasi pemangku kepentingan terhadap identitas ekoregional untuk pengembangan ekowisata masih relatif rendah: dari 327 tipe identitas ekoregional yang dipetakan, hanya 41% yang diakui oleh pemangku kepentingan. Identitas ekoregional yang sedang tren dan memiliki nilai ekonomi signifikan saat ini adalah Kopi Gayo, Danau Lut Tawar, dan Ikan Depik, yang memiliki orientasi pemangku kepentingan tertinggi di Kabupaten Aceh Tengah. Fakta ini tidak hanya melemahkan fungsi identitas ekoregional lainnya, yang juga penting untuk pengembangan ekowisata, tetapi juga menyebabkan hilangnya bahkan kepunahan identitas-identitas tersebut.

Kata kunci: konsep, identitas ecoregional, ekowisata, Dataran Tinggi Gayo

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I. INTRODUCTION

An assessment of stakeholder orientation toward ecoregional identity for ecotourism development is important as a review of the attitudes of various views, interests, and desires of stakeholder elements on this ecoregional identity. Shafieisabet and Haratifard (2020), Cunha et al. (2020), and Grilli et al. (2021) stated that stakeholder orientation such as current perceptions, motivations, and preferences was important for the development of sustainable tourism and ecosystems. Apart from its relevance to management and utilization, stakeholder orientation is also important for protecting various ecoregional identities in ecotourism development. Ecoregional identity is a characteristic of regional ecology that becomes the identity of a group of people within an area boundary, with ecological characteristics relevant across landscapes, cultures, and ethnicities. Referring to the peculiarities of regional ecology, the combination of identity and ecoregional concepts is deemed important for ecotourism development in overcoming threats to the preservation of regional natural and cultural resources. The concept of identity is important to foster a sense of concern for the environment (Clayton & Myers, 2009) and to overcome local problems together (Del Biaggio, 2015). Meanwhile, the ecoregional approach is important as a sustainable ecosystem management approach to help bridge social aspects from a conservation perspective by understanding the interactions between human groups and their local environment (Blasi et al., 2010). For ecotourism development, the concept of identity is considered important for differentiation, competitiveness, and competitive advantage (Andre, 2011), while ecoregionalism is considered important as a holistic concept for promoting integrated natural resource management (Meloncoviua, 2012). However, until now, no one has combined the two concepts into the concept of ecoregional identity for ecotourism development.

Ecotourism is a tourism concept that can provide mutual benefits among tourists, local communities, and the environment through efforts to conserve local natural resources and culture. Avenzora (2008) states that ecotourism has a complex meaning and should be simplified through a spatial approach, because the characteristics of tourism activities differ from one place to another, even when the resources are the same. Thus, ecotourism as a tool for sustainable development to address all environmental, social and economic problems at once (Durr & Wither, 2018), and the goal of ecotourism to connect local communities with conservation (Butcher, 2003) can be achieved.

The developing ecotourism euphoria, which adds to the complexity of conservation in ecotourism development, becomes increasingly complicated by the threats to the preservation of the region's natural and cultural resources. One of the districts in the Gayo Highlands of Aceh Province, which is promoting ecotourism, is Aceh Tengah. The area has the potential for specific unique natural resources and regional culture, which are currently being exploited to promote and market it as a tourist attraction. If the various potential tourist objects are not managed and utilized optimally, it will leave a negative footprint and threaten the preservation potential of the region's natural and cultural resources. Thus, the concept of ecoregional identity needs to be immediately echoed and better communicated as an ecotourism strategy that can provide an alternative model in planning and designing the utilization of local potential of natural and cultural resources for ecotourism development. Ecoregional identity can be a solution to overcome identity conflicts among stakeholders, and serve as a model for ecoregional identity that can be marketed and promoted in ecotourism development.

With various considerations described above, it is important to conduct this research in a structured and measured manner to explore, map, and analyze orientation of stakeholders in utilizing various existing ecoregional identities for ecotourism development in Aceh Tengah District, Aceh Province. Therefore, this study aimed to explore various things related to ecoregional identity for ecotourism development and to analyze stakeholder orientation patterns regarding ecoregional identity for ecotourism development in Aceh Tengah District.

II. MATERIAL AND METHOD

A. Study Site/Location and/or materials

The research was conducted from August to October 2018 in the Gayo Highlands area of Aceh Tengah District, Aceh Province. Geographically, Central Aceh District is located at 4°10 '33 "- 5°57'50" N and 95°15'40 "- 97°20'25" E, bordering the Bener Meriah district to the north, the Gayo Lues District to the south, the Nagan Raya District to the west, and the Aceh Timur District to the east. Judging from the topography, the Aceh Tengah region lies at altitudes of 850 to 2600 m above sea level, with rainfall ranging from 1900 to 3000 mm per year.

B. Methods

This study uses a phenomenological approach, and data collection through participant observation is to understand the participants' essential phenomena in their life experiences (Nazir, 2014; Creswell, 2009). The research implementation began with analyzing various secondary data on the potential of ecoregional identities for ecotourism development, resulting in the Potential Ecoregional Identities for Ecotourism Development in Central Aceh Regency (Table 1). This table is used to design a series of surveys to explore, map, and analyze stakeholder orientations, namely by using a semi-closed questionnaire. The data collection process was carried out in two stages: 1) the classification stage, where data were collected in the form of perception and motivation data, and 2) the verification stage, where data were collected in the form of preference data. Questions for perception were asked which ecoregional identity potentials were known to respondents, and questions for motivation were asked, which ecoregional identity potentials were preferred by respondents for each assessment aspect (ecological and conservation, socio-cultural, socio-economic, socio-political, development, territorial, and ecotourism). Meanwhile, questions for preference were asked which ecoregional identity respondents preferred for ecotourism development. Answers were scored on a scale of 1 to 7, adopting a one-point-one-indicator scoring system (Avenzora, 2008).

Classification Phase. The clarification phase was carried out to obtain stakeholder orientation on ecoregional identity for ecotourism development through an analysis of the perception and motivation of stakeholders in the Gayo Highlands, Aceh Tengah District. Listyana and Hartono (2015) states that perception is a process within oneself that enables one to know and evaluate, and that it determines the impression of the surrounding environment. Crompton (1979) and Needham and Little (2013) state that motivation is a series of biological and spiritual desires and needs that encourage us to perform certain tasks or engage in certain activities.

Table 1. Potential of ecoregional identity for ecotourism development in Aceh Tengah District.

No.	Potential of ecoregional identity	The number of elements identified
	Potential natural resources	
1	Rare plants	8
2	Endangered animals	8
3	Endemic species	1
4	Species of cultural key	27
4	Regional potential	24
5	Natural phenomena:	
	a. River	1
	b. Water fall	4
	c. Lake	3
	d. Cave	6

No.	Potential of ecoregional identity	The number of elements identified
	Potential natural resources	
	e. Mountainous landscape /Pine forest	4
	f. Mountain	2
	g. Fog	1
	h. Cold weather	1
6	Agricultural and horticultural commodities	10
7	Plantation commodities	14
8	Potential of forestry:	
	a. Timber forest product	12
	b. Non-timber forest product	12
9	Fishery commodities	4
10	Livestock commodities	5
11	Industrial commodities	12
12	Tourism commodities:	
	a. Nature tourism	43
	b. Culture tourism	12
	c. Artificial tourism	6
	d. Agro-tourism	2
13	Mining and energy commodities:	
	a. Mining	6
	b. Energy	2
	Potential of culture	
1	Equipment and living tools:	
	a. Traditional weapon and production tool	22
	b. Traditional culinary	7
	c. Traditional costum	1
	d. Traditional house	1
2	Livelihood and economic system	9
3	Social system:	
	a. Kinship	9
	b. Customary institution (Kejerun)	7
	c. Legal system	3
	d. Marriage system	2
	e. Customary governmental system	1
	f. Customary regional system	5
	g. Custom	6
4	Language	2
5	Art	10
6	Knowledge system	7
7	Belief system	5
	Total	327

This analysis is important to determine the knowledge and motivation of stakeholders' desire for an ecoregional identity for ecotourism development that has been identified in Table 1. Related to the interest of stakeholders, ecoregional identity is classified into seven important aspects of assessment, namely ecological and conservation aspects, social-cultural, socio-economic, socio-political, development, regional, and ecotourism. Ecological and conservation aspects encompass all steps in regulating and understanding the complex relationships between humans and their environment to conserve biodiversity and ecosystem services (Buckley, 2010; Blasi et al., 2010). These various ecological systems are unique, complex, and dynamic, thus requiring specific conservation efforts, resulting in specific and unique socio-cultural, socio-economic, socio-political, development, regional, and ecotourism aspects. Thus, these seven aspects are important for the development of ecotourism, as it is multidisciplinary and multisectoral, giving rise to dynamics of reciprocal causality and correlation among ecological aspects related to conservation. Meanwhile, conservation requires socio-cultural and socio-economic support that affects on socio-politics, development, territory, and ecotourism.

At this stage, 30 respondents were selected from each stakeholder group, namely institutional groups (government and non-government institutions), indigenous peoples, the general public, and tourists. The four stakeholder groups that have a role and interest in selecting an ecotourism identity for the ecotourism development. The respondents were determined through purposive sampling based on the following criteria: a). being adults, b). residing in the district of Aceh Tengah, c). knowing well the environment and the dynamics of life in Aceh Tengah District, and d). having wide public recognition as one of the informal figures who can be serve as a source of knowledge for the community in their environment. Particularly for respondents from the Institution group, the determination was also based on the rank of their formal position in the institution; and respondents from selected tourist groups traveling to Aceh Tengah District.

Verification Phase. This phase was conducted to confirm the ecoregional identity for ecotourism development through stakeholder preference analysis in the Gayo Highlands, Central Aceh Regency. Preference analysis is important to find out the choices and decisions of stakeholder respondents on ecoregional identity for ecotourism development. The purpose of the verification phase was to validate the ecoregional identities that the stakeholder group had stated in the Clarification Phase. In the verification phase, the number of respondents involved was 90 respondents from 3 stakeholder groups, namely institutional groups, indigenous peoples and the general public. The three stakeholder groups have power and influence in determining ecoregional identity for ecotourism development.

C. Analysis

The data from stakeholder respondents were analyzed using the One Score One Criteria/ Indicator System, with various tabulated. In principle, the One Score One Criteria/Indicator System analysis is an analysis method aimed at avoiding systematic bias in determining evaluation criteria, both in terms of enforcing the validity of the linearity of the criteria used and to avoid multi-interpretation bias in interpreting the resulting scoring (Avenzora, 2008); where each criterion that is built must be discrete, so that each score produced can be ensured that it is free from the multicorelianity effect and can directly become a reliable basis for the existence of a resulting score. So, in this study, every issue that was being researched was mapped to 7 independent aspects, each defined by 7 criteria that influenced it independently.

All results obtained from both the classification and verification phases were carried out by statistical tests through the Spearman Rank correlation test using the SPSS 25 program, in the classification phase the analysis was analyzed to see the nature of the correlation of the seven important aspects of the assessment of the data obtained in each group of respondents elaborated; is in the verification phase in the analysis to see the nature of the correlation between stakeholder groups.

III. RESULT AND DISCUSSION

Classification Results.

Stakeholders' Perceptions of Ecoregional Identity for Ecotourism Development. Stakeholders 'perceptions in the classification phase are important as a first step to understand the respondents' perspectives and knowledge on the potential of ecoregional identity for ecotourism development. The analysis shows that stakeholder perceptions of ecoregional identity for ecotourism development remain low. Generally, stakeholders don't understand the important value of each ecoregional identity for ecotourism development because this is a new concept for stakeholders. As many as 327 potential ecoregional identities were identified (230 natural resource potentials and 97 regional cultural potentials), respondents knew and chose only 41% of these (Table 2). The low knowledge of respondents on various potential ecoregional identities indicates a lack of awareness among individuals and populations, as well as low indicators of socialization to development information on conservation that are running in the district. Leeuwis (2009) states that perception is closely related to the concept of information, while Hateftabar and Chapuis (2020), Cho and Yang (2018), and Lucrezi et al. (2013); state that perception is the first step to predict the attitude of developing motivation and preferences of individuals or groups.

Several authors, such as Csikszentmihalyi (1975), and Tsaur, Lin, and Yen (2020), state that perceptions are influenced not only by differences in environment, location, and activities, but also by differences in professional backgrounds and the attention of respondents. So, it is very possible that there are differences in perceptions among stakeholder groups regarding ecoregional identity for ecotourism development; therefore, it is necessary to socialize information on various potential ecoregional identities for ecotourism development as a whole.

Stakeholder Motivation for Ecoregional Identity for Ecotourism Development. A stakeholder motivation analysis is needed to determine the respondents' motivations as a form of attitude towards ecoregional identity for ecotourism development, mapped onto seven important assessment aspects that are interrelated. Based on the analysis obtained stakeholder polarization of ecoregional identity is presented in Figure 1 for seven important aspects of the assessment, with the highest score (Figure 1a) and the lowest score (Figure 1b). The ecoregional identity with the highest score is considered important, and the ecoregional identity with the lowest score is considered less important by stakeholders. However, the various ecoregional identities actually have their respective important values for the function of the 7 important aspects of assessment, both ecological and conservation aspects, socio-cultural, socio-economic, socio-political, development, regional, and ecotourism.

Ecology and Conservation Aspects The analysis results for this aspect obtained ecoregional identities with the highest scores, namely Gayo Coffee, Depik Fish, Pine Forest Landscapes, and Lut Tawar Lake (Figure 1a), and ecoregional identities with the lowest score, namely Customary Procession Plants, Nepenthes, Endemic Habitats, Wildlife Corridors, Orangutans, and Rom Puteh Rice (Figure 1b). The various ecoregional identities obtained when viewed from ecological and

Table 2. Perception of stakeholders on potential of ecoregional identity for ecotourism development at Tengah District.

No	Stakeholder groups	Potential of ecoregional identity		Total average	Total score classification
		Natural resources (230 types)	Local culture (97 types)		
1	Institution	28%	46%	37%	5714
2	Indigenous people	40%	56%	48%	7671
3	General public	39%	48%	44%	6962
4	Tourist	29%	41%	35%	6236
	Total average			41%	6646

conservation functions all have important values for the protection function of Essential Ecosystem Areas, environmental services, endangered species, conservation areas, endemic species, iconic species, and Key Cultural Species. Studies conducted by Stern and Axt (2020) and Palma et al. (2020). Gilbert (1989, 2005, 2014) has shown that low individual motivation can lead to low awareness in the population, whereas the results of the study by Bopp et al. (2019), and Panzer and Krause (2020) show that low motivation will lead to neglect of the potential use of natural resources.

Gayo coffee (Gayo coffee) is considered important today by all people in Aceh Tengah District; Apart from being a superior commodity which has important economic value, this identity is also becomes the motivation for the community to protect forests and nature. According to Khalid (2017), the demands of the global market require that Gayo Coffee must be from environmentally friendly plantations, and follow the rules of the Green Certification (Eco Labeling) program such as Organic, Fair Trade, CAFÉ Practice, Rainforest Alliance, and Utz Certified. However, another fact in the field, due to the market demand and the high price of Gayo Coffee has caused forest and land degradation. In line with research conducted by Ellyanti et al. (2012) and Salima et al. (2012), Gayo Coffee has ideal growing requirements at an altitude of 900 - 1700 m above sea level to produce good quality beans with a distinctive aroma and taste; thus, causing the expansion of coffee plantations towards forests and mountains. Likewise, Depik fish (*Rasbora tawarensis*) is considered important as an endemic species that is only found in Lut Tawar Lake; which has become one of the identities of the community and the region. However, currently, Depik fish continues to experience population decline due to environmental degradation, introduction of foreign fish, destructive fishing techniques, pollution, and global climate change (Muchlisin, 2008). Meanwhile, the Pine Forest Landscape is considered important as a homogeneous natural forest which is the specialty of the Gayo Highlands Forest. As for Lut Tawar Lake, besides being used for recreation and fishing; also functions as a source of water from 22 large rivers and 16 small rivers in the Aceh Tengah District (Gayosia et al., 2015).

Although the results of the analysis show that the Orangutan (*Pongo abelii*) is considered less important by stakeholders, this identity has an important value for the protection of endangered species both at the national and international levels. At the national level, one of them is done by the Ministry of Environment and Forestry (KLHK) which launched the 2019-2029 Orangutan Conservation Strategy and Action Plan (SRAK) which was endorsed by the Decree of the Minister of Environment and Forestry Number SK.308/MENLHK/KSDAE/KSA. 2/4/2019. Likewise, the Kantung Semar (*Nepenthes* sp.), has an important value for the protection function of wild plants of tropical carnivorous plants that function as biological plants for insect control (Suwardi & Navia, 2015). Meanwhile, Traditional Procession plants also have important value for the Gayo ethnic community as a Cultural Keystone Species (CKS) used for customary processions.

Likewise, Rom Puteh Rice which is also considered less important, even though it actually has important value for the protection of the local Gayo rice species which is rare and rarely cultivated. These results not only show the lack of information dissemination and the insufficient contact with the conservation programs that have been carried out so far, but imply the threat of extinction for various important species in the district of Aceh Tengah. Studies conducted by Dickman, et al. (2015), Becker et al. (2007), and Saunders (2003) have shown that low awareness of the value of conservation of important species is caused by low governance and regional economic wealth which has a negative impact on the extinction of these species which are difficult to replace.

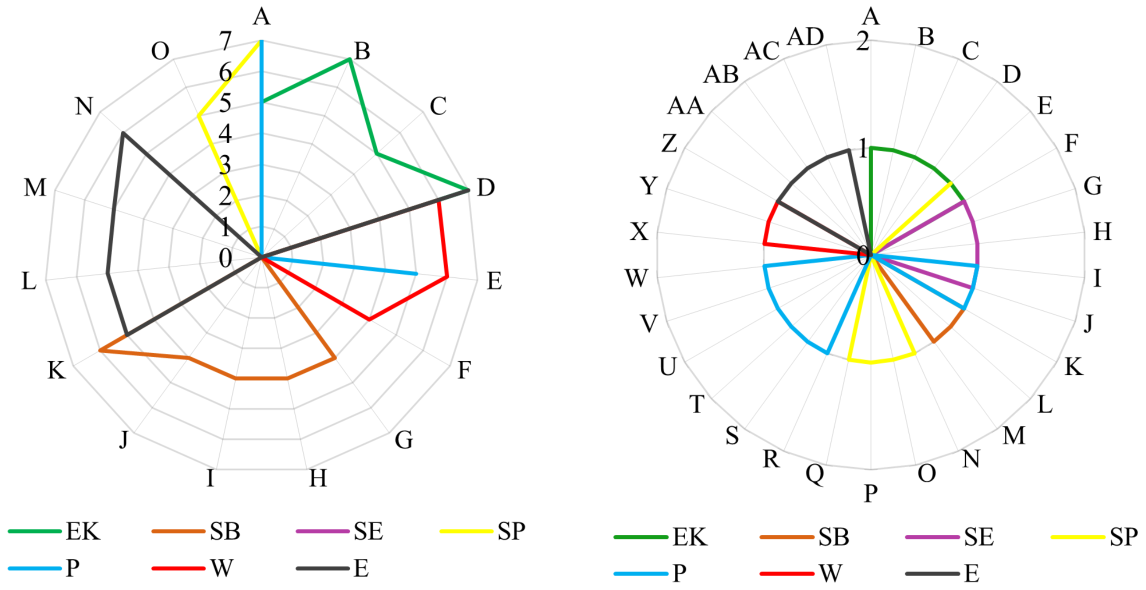

Figure 1. Stakeholder's motivation polarization of Aceh Tengah ecoregional identity in seven important aspects of the assessment.

Remark:

EK= Ecological and Conservation Aspects; SB= Social and Culture; SE = Social and Economic; SP = Social Politics; P = Development; W = Region; E = Ecotourism.

a. Highest score:

A= Gayo Coffee; B=Depik Fish; C= Pine Forest Landscape; D= Lut Tawar Lake; E= Nature Tourism; F= Plantation; G= Gayo language; H= Kerawang Gayo; I= Gardening; J= Farming; K= Didong Dance; L= Horse Racing; M= Coffee Plantation; N=Asam Jaing (traditional culinary); O= Sara Opat (customary government system)

b Lowest score:

A=Indigenous Procession Plants B= Nephentes; C=Endemic Habitat; D=Wildlife Corridor; E=Orangutan; F=Rom Puteh Rice (Local Rice); G= Lut Tawar Red Onion; H= Gold Mining; I=Non Timber Forest product; J=Gayo Avocado; K=Trading; L=Art and Culture; M=Traditional Culinary; N=hunting Garden; O=Customary Law; P=Tiger; Q=Natural Forest; R=Cocoa; S=Cane; T=Grupel Wood; U=Auction Market; V=Culture Tourism; W=Agriculture; X=Deer; Y=Traditional Guel Dance; Z=Pine; AA=Floating Café; AB=Loyang Mendale Cave; AC=Puteri Pukes Cave; AD=Cold Weather

Furthermore, threats to wildlife and important areas are also reflected in the lowest scores given for Endemic Habitats and Animal Corridors that have important values for the protection of endemic species, rare species, and endangered species; for example, Lut Tawar Lake is an important habitat for Depik Fish, while the Animal Corridor is an important solution related to habitat fragmentation. Atmoko et al. (2014) state that animal corridors are a key landscape element that functions to improve connectivity between fragmented habitats so as to facilitate the movement of animals within and between fragmented habitats. As for Nature Tourism, although currently considered less important, it has an important value for the function of utilizing various potential natural objects available.

Socio-Cultural Aspects Culture has an important role and function in the course of human life related to the environment and nature. Culture and the environment have a very close relationship, as pointed out by Hsu and Huang (2016), that the essence of culture is a symbol of recognition of the fundamental relationship between local communities and heritage, humans and the environment. As for Setiadi et al. (2010) states that the form of socio-cultural aspects can be seen based on the seven cultural elements that are incarnated in cultural systems, social systems and material systems. Based the analysis results, the ecoregional identities with the highest scores were obtained, namely Gayo Language, Gayo Kerawang, Gardening, Farming and Didong; ecoregional identities with the lowest score were namely Trade, Cultural Arts and Traditional Culinary.

Didong is a traditional dance of the Aceh Tengah Gayo ethnic which is considered important by all stakeholders. Afriadi (2018), states that Didong art is a combination of dance, vocal and literary elements that played an important role in uniting the gayo ethnicity who have various opinions regarding morals and aesthetics. In addition, Didong is also a poem media containing religious values, beauty values and togetherness values, which were previously used as a means of spreading Islam (Directorate of Cultural Heritage and Diplomacy of the Indonesian Ministry of Education & Culture. 2018). Whereas farming is considered important as the main livelihood for the Gayo local community; about 99% of Aceh Tengah population from the total 204,273 people, have main jobs as farmers (Aceh Tengah Dalam Angka, 2018). As for the Gayo Language, although dialects differ slightly between sub-tribes, such as the Gayo Lues dialect, Gayo Kalul, Gayo Serbajadi / Lokop, Gayo Deret and Gayo Lut (Audia et al., 2016), are considered important by stakeholders for the language function as the unifier of the Gayo ethnicity. Gayo. Likewise, Kerawang Gayo is considered important as a cultural element that has high cultural value. Salihin et al. (2019) states that Kerawang Gayo is the result of the creation of Gayo ethnic culture through a process of spontaneous thinking, then deep reflection so that it raises a motive that has a philosophical meaning related to the life of the Gayo community.

Some other ecoregional identities are considered less important by stakeholders such as Cultural Arts, but these identities also have important values as a function of regional special arts that have their own uniqueness, including carving, painting, literature, poetry, singing, and others. Traditional culinary also has an important value as an element of regional culture as a result of people's knowledge of the surrounding environment which produces a unique taste and is different from other regions. Likewise trading, also has an important value as the main support in managing and utilizing the potential of natural and cultural resources of the region. Various ecoregional identities that are considered less important by stakeholders actually have important values for the function of the socio-cultural aspects of the people of Aceh Tengah. The lowest score given by stakeholders not only shows the people's ignorance of the various cultural elements in their area, but it is an opportunity to lose or even extinction of these cultural elements from the Gayo ethnic community of Aceh Tengah. Duran et al. (2015) and Perez-Hernandez et al. (2020) states that low awareness and sensitivity to cultural elements can cause cultural elements to disappear.

Socio-Economic Aspects Socio-economy is related to all activities that support a person's position in a group and region. Weihrauch-Bluher et al. (2018) and Pearce et al. (2012), states that the socio-economy is related to education, employment and income of local communities which can lead to behavior. Based on the analysis results, shown in Figure 1 is the ecoregional identity with the highest score, namely Gayo Coffee; The ecoregional identities with the lowest score were Rom Puteh Rice (*Oryza sativa* L), Lut Red Onions (*Allium cepa* L. var. aggregatum), Gold Mining, NTFPs, and Gayo Avocado (*Percea Americana*. Mill).

In terms of socio-economic aspects, Gayo Coffee is considered important as a superior and regional mainstay commodity that has market opportunities and high selling prices today, both on the national and international markets. Taufiq (2018) states that at the international level the selling price of Gayo Coffee is included in the most expensive category compared to other types of coffee in the world, such as the price offered at the world coffee exhibition organized by the Coffee Association of America (SCAA) specialty organization in Portland, Oregon Convention Center, United States. Supriyanti (2018) also prove that in the regional market the price of Arabica Gayo Wine coffee beans reaches Rp. 397.000.00/kg and the price of ordinary Gayo Arabica coffee is Rp. 100.000.00/kg. Meanwhile, Plantation and Agriculture are considered important as sectors which are the main source of livelihood for most of the Gayo population. Statistical data records that of the total population of Aceh Tengah (51.284 households), as many as 30.900 heads of households work as farmers and/or gardeners (Aceh Tengah Dalam Angka, 2018).

The ecoregional identities that are considered less important, including Tangerines, Lut Tawar Red Onions, Rom Puteh Rice, and Gayo Avocados actually have important values as potential for plantation and agricultural commodities that have the opportunity to increase community income and the regional economy, as well as Depik Fish and Coffee Plantation. Depik fish is sold in the market reaching 80 thousand per kilogram (Field Survey Data, 2019), and coffee plantations are the main sector of people's livelihoods; Statistical data notes that the majority (100%) of coffee plantations in Aceh Tengah are smallholder coffee plantations (Aceh Tengah Dalam Angka, 2018). Furthermore, NTFPs also have an important value as a potential forest resource which turns out to also have an economic value that is no less high than Gayo Coffee, for example Jernang.

The ecoregional identity of Gold Mining even though has the highest economic value and has quite high potential as well, including those already identified in the sub-districts of Rusip Antara, Celala, Linge, Jagong Jegel, Ketol, and Silih Nara (Aceh Mining and Energy Office, 2018), are still considered less important by stakeholders today. Concerning about the bad impact on the environment and the upstream area of several important rivers in Aceh, it is also feared that it will have a negative impact on the sustainability of coffee plantations as the green gold of the current Gayo Highlands region. This concern is also in line with the research produced by Cristescu et al. (2012), Alvarez-Berríos and Aide (2015), and Screwdriver et al. (2019), that gold mining can cause environmental degradation with adverse effects that are detrimental to flora and fauna, and can inhibit vegetation growth for a long time.

Socio-Political Aspects In a political context, society is an actor so that it cannot be separated from political elements, and specific forms of community interaction behavior can certainly raise to specific socio-political aspects. Fay (1991) states that socio-politics is related to humans, power, rules and authority. It can be said that politics always controls and is at the highest level in people's lives. The analysis results presented in Figure 1 for the socio-political aspect are the ecoregional identity with the highest score, namely Gayo Coffee and Sara Opat, and the ecoregional identity with the lowest score, namely Taman Buru, Customary Law, Tiger, and Natural Forest.

Gayo coffee has had a major influence on the development of the Gayo Highlands region, especially Aceh Tengah district. In addition to raising the popularity of the Gayo Highlands which were previously marginalized in the Aceh Province, Gayo Coffee is also now well known in the international market as Gayo Mountain Coffee (ICCRI, 2008); already has a GI certificate (Geographical Indication) issued by the Ministry of Law and Human Rights Republic of Indonesia on May 27, 2010 (Ellyanti et al., 2012). Meanwhile, Sara Opat is considered important as a customary government system that gave birth to customary institutions and laws, where currently this identity is still valid in the village level of government structure in the Aceh Tengah district (Surya & Suhartini, 2019), especially for resolving minor crimes. in the Gayo local community according to the mandate of the Aceh Qanun Number 9 of 2008 article 13 paragraph 1 concerning the fostering of customary life.

Even though the lowest score is given to Customary Legal, this identity actually has an important value as a law that runs according to Islamic Syariah with a combination of the values of the Gayo ethnic customs and culture born from the Sara Opat government system. This fact can unwittingly weaken the function of customary legal in the society. Likewise, Hunting Parks, Natural Forests and Tigers and Orangutans are also considered less important by stakeholders, but functionally have important values in socio-political aspects. The low score given to this identity indicates a lack of conservation echo launched by either the government, NGOs or other related institutions. If the important areas and animals that have been designated and protected by the government are deemed meaningless, then it can be said that political power has lost its meaning for the community.

Development Aspects Development is important to produce changes for the better for the community, region and the environment. Riyadi and Bratakusumah (2005) state that development is a process to make changes for the better, which is carried out in a planned manner. The analysis results for this aspect are presented in Figure 1 in the form of ecoregional identity with the highest score and considered important by the important stakeholders, namely Gayo Coffee and Nature Tourism; The ecoregional identity with the lowest score is considered less important, namely NTFPs, Avocado, Trade, Cocoa, Sugarcane, Grupel, Auction Market, Cultural Tourism and Agriculture.

Actually, the resulting ecoregional identity has an important value for the aspect of development; according to the statistical data, all of them are among the contributors to the GRDP of Aceh Tengah district. Examples of Agriculture, Gayo Coffee, Cocoa, Sugarcane, Avocado and Grupel are included in the categories of contributors to Aceh Tengah GRDP in the last 5 years (BPS Aceh Tengah, 2013-2017). In addition, Nature Tourism and Cultural Tourism are also the tourism business sector which currently has a great opportunity to increase employment and welfare of the local community and the regional economy. Margaryan and Fredman (2017) and Chung et al. (2018) stated that in addition to increasing employment opportunities, increasing the economy of the local community and the region, nature tourism can also preserve biodiversity and other natural objects can bring changes to improve people's welfare. Torre and Scarborough (2017) and Haigh (2020) states that Cultural Tourism has a great opportunity to improve the economy and welfare of the local community and increase regional income if it is presented through a series of commercial and social activities to bring out subjective experiences from tourists.

Trade has been also one of the sectors that ranks fourth as a contributor to the increase in PDRB Aceh Tengah in the last 5 years (BPS Aceh Tengah, 2013-2017). Furthermore, the auction market has an important value related to the marketing of plantation and agricultural commodities. The Aceh Tengah Auction Market was held as an effort to break the long sales chain and has always been detrimental to farmers so far, so that farmers can enjoy the highest selling price in marketing their products to national and international markets.

Regional Aspects Territory is an area of control over various potential natural and cultural resources of the region. According to Rustiadi et al. (2009) states that an area is an area with general characteristics or a specific spatial structure, which functions to differentiate one area from another, in natural, economic, demographic or socio-cultural conditions. The study results are presented in Figure 1 for the regional aspect showing the ecoregional identities with the highest scores, such as Nature Tourism, Lut Tawar Lake and Plantation; ecoregional identities with the lowest scores, including Deer, Guel, and Pine.

Various ecoregional identities that are generated in the regional aspect constitute the potential of regional natural and cultural resources which have important values as assets of regional wealth and pride. For example, Laut Tawar Lake is a natural resource potential which is the identity of the community and the region as the largest and only lake in the Gayo Highlands area. Having an area of approximately 5.671 ha located at an altitude of 1.500 m above sea level (Qanun RIPP Aceh Tengah district, 2019), Lut Tawar Lake also contains another potential identity that is no less important in the form of Depik fish. Depik fish is considered important and has important value as a potential natural resource in the form of endemic species, which are the only species also in the Gayo Highlands. Meanwhile plantations are considered important as a function of strategic areas and important priority areas of the region at this time (RTRW Aceh Tengah, 2016-2032). Likewise, Nature Tourism is considered important as a priority area for the development of various natural tourism objects, in addition to the function of accessibility and availability of infrastructure.

Other important potentials such as Deer (*Cervus timorensis*) and Elephants (*Elephas maximus sumatranus*) are considered less important by stakeholder groups, but in fact this identity has an important value as a potential natural resource that has historical, economic and political values for the Gayo ethnicity. On the other hand, the potential for regional culture such as Guel is also less important, even though it actually has an important value as one of the important cultural elements of the region. Murni (2017) states that Guel is a regional cultural potential with high philosophical, historical and cultural values which are shown at traditional ceremonies and welcoming guests as well as art performance events. The various results presented in this aspect show that people are still not aware of the various natural and cultural potentials they have; the community has not fully utilized the natural and cultural resource potentials in their territory. Ning and Hoon (2011) stated that in the tourism industry, optimal use of natural and regional cultural resources can improve competitiveness and avoid resource conflicts.

Ecotourism Aspects. Ecotourism is ecological tourism, a tourism concept that generates mutual benefits among tourists, local communities, and the environment. So that Li et al. (2012) state that ecotourism must be planned, controlled, and adjusted to the natural values and ecological sensitivity of the area. Meanwhile, Avenzora (2013) states that ecotourism needs to be designed into concepts and products with criteria related to the functions of unique and unique tourism resources, which can fulfill the seven pillars of ecotourism, namely the pillars of ecology, socio-culture, economy, experience, satisfaction, memories, and education. The analysis results for the ecotourism aspect as presented in Figure 1, show the ecoregional identity with the highest score, including Lut Tawar Lake, Didong, Horse Racing, Coffee Plantation, and Asam Jaing; ecoregional identity with the lowest score, including Pinus, Floating Cafe, Mendale Cave, Putri Pukes Cave, and Cold Weather.

Natural phenomenon resources, such as Lut Tawar Lake, and art and cultural tourism resources such as Horse Racing, Didong, and Jaing Tamarind in Figure 7a are considered important and well known to the general public as tourist attractions that have their own specific and unique values. For example, Lut Tawar Lake has a beautiful charm in the form of a combination of lakes, hills, cold air, and pine vegetation that can be enjoyed in one landscape. Likewise, Horse Racing, Didong, and Jaing Tamarind are cultural and artistic tourism resources, as well as culinary tourism, which are the main cultural tourism resources of Aceh Tengah District.

The various ecoregional identities in Figure 7b, which are considered less important in the aspect of ecotourism, actually have an important value as natural phenomena of tourism resources, arts and cultural tourism, flora and fauna tourism, culinary tourism, and also water tourism resources. One of them is the Floating Café, a tourist resource combining natural phenomena and cultural tourism that has just been discussed by some people and is very promising for development at Lut Tawar Lake. Xue et al. (2017) state that, for tourist purposes, a new identity can be presented based on a representation of local culture, traditions, and heritage, alongside socio-economic conditions.

All the ecoregional identities for the ecotourism aspect in Figure 1b, when viewed from the function of the ecotourism aspect, have an important value to increase the economic, ecological, and cultural benefits of the local community. However, the low score given for this ecoregional identity is thought to be due to the inadequate utilization and management of potential ecotourism resources at this time, and there are no examples of ecotourism management that provide significant economic benefits to the community and the region.

Rank Spearman. The relationship between various study results on various aspects of producing the ecoregional identity above is seen and analyzed using the Spearman Rank correlation test; the results are shown in Table 3. The correlation of the various aspects shown in Table 3 shows that the various scores given by each group of respondents on various elements of ecoregional identity (as disclosed in Figure 1) indicate the relationship between aspects that can be accepted and trusted as an orientation for the sample population as a whole.

Table 3 shows that, in addition to a significant and positive correlation between aspects, there is a negative relationship, namely between socio-political aspects and ecotourism aspects (-0. 061). This happens because respondents generally think that the ecotourism aspect has nothing to do with politics, and in matters related to ecotourism aspect, the politics of ecotourism is very rarely discussed. It should be realized that, actually, ecotourism development is under the influence of political leadership (Liang & Chan, 2018); and socio-political aspects are actually important to produce policies by helping different stakeholders agree on a common understanding and language in development management (Makki et al., 2015).

Verification Result

Stakeholder preference for ecoregional identity for ecotourism development Reassessment of various ecoregional identities generated in the classification phase based on stakeholder preferences in the verification phase is important and should be considered as an effort to confirm and validate ecoregional identities for ecotourism development. Jun et al. (2015), Thoits (2003), Stryker (1981), and Burke and Stets (1999) state that confirmation efforts through the verification process can build and maintain identity through the positive emotions that are generated, thus affecting activity and commitment to the identity. Thus, confirmation and validation of ecoregional identity can avoid conflicts, thereby maintaining the sustainability of local natural and cultural resources for ecotourism development. The results of the analysis in Figure 2 show that the ecoregional identity with the highest score is considered important (Figure 2a) and the identity with the lowest score is considered less important by stakeholders (Figure 2b).

Table 3. The results of the Spearman Rank correlation test among aspects of the assessment.

	1	**2**	**3**	**4**	**5**	**6**	**7**
1	1	0. 533**	0. 235**	0. 139	0. 322**	0. 276**	0. 271**
2		1	0. 302**	0. 222*	0. 316**	0. 396**	0. 430**
3			1	0. 428**	0. 472**	0. 353**	0. 080
4				1	0. 274**	0. 332**	-0. 061
5					1	0. 416**	0. 145
6						1	0. 261**
7							1

Remark: 1=Ecology & Conservation; 2= Socio-Culture; 3=Socio-Economic; 4=Socio-Politics; 5=Development; 6=Region; 7=Ecotourism.
**) significant correlation at level of 1%; *) significant correlation at level of 5%

Figure 2 still shows differences in choice between stakeholder groups, as shown in Figure 1, although all the ecoregional identities produced have important values for ecotourism development. This further shows that each stakeholder group has its own choices and decisions on ecoregional identity for ecotourism development. The results of the Rank Spearman correlation test (Table 4) show no significant correlation; only unidirectional (positive) and unidirectional (negative) relationships are observed. This shows that between stakeholder groups do not have an important correlation with each other. This could be due to the attitude of each group on ecoregional identity for ecotourism development, which is influenced by the characteristics of the respondents, as well as because of the group's background. Karas and Cieciuch (2018) state that the respondent's decision to choose an identity is closely related to the development of identity, starting from the process of exploring

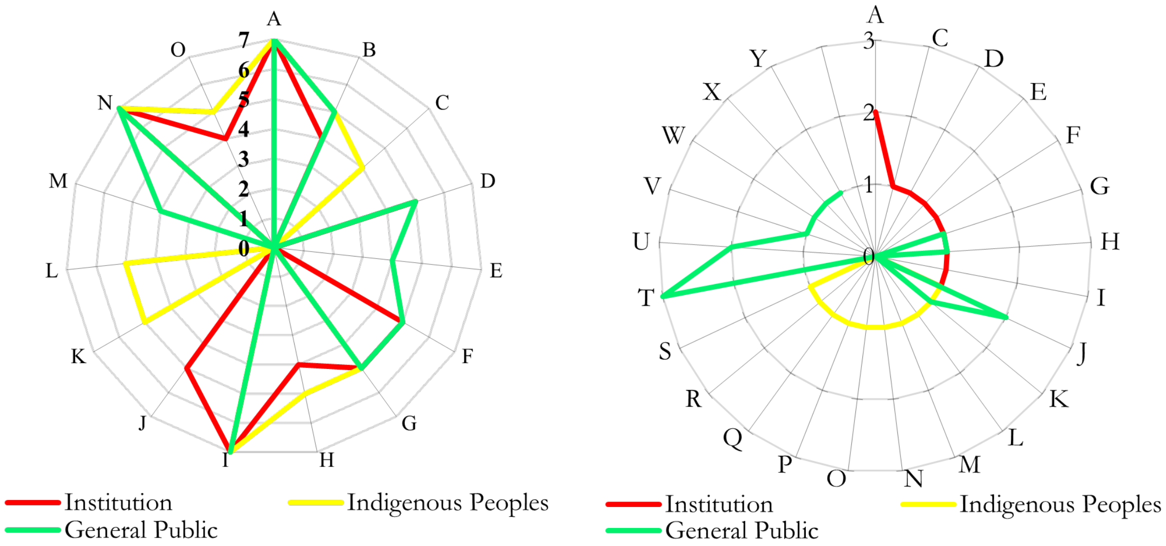

Figure 2. Ecoregional identity with the highest score (a) and ecoregional identity with the lowest score (b) at verification phase.

Notes:

a. Highest score ecoregional identity:
A= Gayo Coffee; B=Cultural Tourism; C= Horse Racing Kuda; D= Nature Tourism; E= Cave; F= Pine Forest Landscape; G= Kerawang Gayo; H= Coffee Plantation; I= Lut Tawar Lake; J=Sara Opat; K=Elephant; L= Custom; M=Jaing Tamarind; N= Depik Fish; O= Didong.

b. Lowest score ecoregional identity:
A=Renggali; B= Asam Jaing; C=Deer; E=Guel Dance; F=Cave; G=Arung Jeram; H=Orangutan; I=Cave Mendele; J= Kantung Semar; K= Orchid Kantung; L= Cold Weather; M=Pengat Gayo; N= Natural Forest; O=Customary Institution; P=Leuser Ecosystem Region; Q=Pine Forest; R=Mountainous Landscape; S=Horticulture; T=Gayo Horse; U=Loyang Koro Cave; V=Custom; W=Sining Dance; X=Forest Orchid; Y=Elephant; Z=Endangered Animal.

Table 4. Result of *Rank Spearman* correlation test among stakeholder groups at Central Aceh Regency

Rank Spearman	**Institution**	**Indigenous people adat**	**General public**
Institution	1	-0. 034	0. 168
Indigenous people		1	0. 248
General public			1

the various alternatives provided to be selected according to one's personal goals, beliefs, values, and desires. Therefore, it can be said that the various information about ecoregional identity presented in Figure 2 is considered confirmed and accepted as an agreement on the interest group's orientation toward ecoregional identity for ecotourism development in Aceh Tengah district.

Based on the results from the two phases above, the highest priority for stakeholders is the leading ecoregional identity, which is well known and has important economic value today. This fact can have negative consequences for other ecoregional identities, which also have important values for ecotourism development. Makki et al. (2015) and Sani and Mahasti (2012) stated that the importantance of identity is needed in facing environmental change, as well as in protecting and promoting the potential of local natural and cultural resources for sustainable tourism development.

IV. CONCLUSION

Stakeholder orientation towards ecoregional identity in Central Aceh Regency remains low and tends to be directed towards developing high economic potential. This low stakeholder orientation is caused by: 1) minimal socialization from the government and related elements regarding ecotourism conservation and development, 2) the absence of examples of potential utilization of natural and cultural resources in the region that provide sustainable economic value in ecotourism development to date, and 3) changes in community behavior and socio-culture due to the pressure of economic needs and global information flows. Therefore, efforts are needed to build and strengthen ecoregional identity among individuals and community groups, so that the natural and cultural resources of the region remain sustainable and do not become extinct.

RECOMENDATION

Ecoregional identity needs to be spelled out in regional qanuns to become a legal umbrella as legal recognition in planning and designing ecotourism development based on ecoregional identity to ensure the preservation of potential natural and cultural resources in a sustainable manner.

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Or

Whitney and Rolfes (2011) state the body requires many nutrients to function but highlight that water is of greater importance than any other nutrient.

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