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Contents

OPTIMIZING CHARCOAL PRODUCTION: A COMPARISON OF THREE WOOD SPECIES AND METHODS

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OPTIMIZING CHARCOAL PRODUCTION: A COMPARISON OF THREE WOOD SPECIES AND METHODS. For sustainable forestry management and environmental protection, it is crucial to compare three wood types and processes in order to optimise charcoal production. The purpose of this study was to evaluate the viability of using diverse waste materials and carbonization techniques to produce wood charcoal. The upcountry wet zone and low-country dry zone regions of Sri Lanka provided the samples, which were each repeated ten times and came in three different sample sizes. To make charcoal, these samples were put through the barrel and pit processes. The results showed that the barrel method produced 28% charcoal instead of the 21% produced by the pit method, demonstrating its higher efficiency and cost-effectiveness. This improvement was ascribed to the barrel's enhanced ability to regulate airflow and temperature during pyrolysis. The study emphasizes the use of wood off-cuts and the barrel method to increase efficiency, save costs, and improve charcoal quality. It provides helpful advice for small charcoal producers.

Keywords: Barrel method, charcoal, off cuts, pit method

OPTIMASI PRODUKSI ARANG: PERBANDINGAN TIGA JENIS KAYU DAN METOD. Untuk pengelolaan hutan berkelanjutan dan perlindungan lingkungan, penting untuk membandingkan tiga jenis dan proses kayu guna mengoptimalkan produksi arang. Tujuan dari penelitian ini adalah untuk mengevaluasi kelayakan penggunaan beragam bahan limbah dan teknik karbonisasi untuk menghasilkan arang kayu. Daerah zona basah pedalaman dan daerah dataran rendah kering di Sri Lanka menyediakan sampel, yang masing-masing diulang sepuluh kali dan datang dalam tiga ukuran sampel berbeda. Untuk membuat arang, sampel ini dimasukkan melalui proses tong dan lubang. Hasilnya menunjukkan bahwa metode barel menghasilkan 28% arang dibandingkan dengan 21% yang dihasilkan metode lubang, sehingga menunjukkan efisiensi dan efektivitas biaya yang lebih tinggi. Peningkatan ini dianggap berasal dari peningkatan kemampuan laras untuk mengatur aliran udara dan suhu selama pirolisis. Kajian tersebut menekankan penggunaan metode potongan kayu dan metode tong untuk meningkatkan efisiensi, menghemat biaya, dan meningkatkan kualitas arang. Laporan ini memberikan saran yang bermanfaat bagi produsen arang kecil.

Kata kunci: Metode tong, arang, potongan kayu, metode lubang

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I. INTRODUCTION

Wood has intertwined itself with the story of humanity, serving as a vital companion since the dawn of our existence. From the earliest sparks of civilization, humans have embraced this versatile resource, shaping its essence to fulfil our most fundamental needs. Humans have used wood for the construction of tools, machinery, furniture, fuel wood, and charcoal (Olorunnisola, 2023). Lightweight black carbon made by burning wood with minimal air which is known as Charcoal can be the best domestic fuel (Fraga et al., 2022). Almost any organic material, including wood, straw, coconut shells, rice husks, and bones, can be used to make charcoal (Nyemba et al., 2018). The hardwood types of wood such as acacia and mangroves are typically selected for manufacturing charcoal. The largest production can be found in Nigeria, Ethiopia, and Brazil but coconut shells are commonly applied in Sri Lanka (Allué et al., 2021). In the past, charcoal was an important fuel for metalworking. With the introduction of coal and raw coal for the smelting of iron, charcoal lost almost all of its importance and was only used as fuel in a specific metallurgical process where a higher fuel purity was needed (Crewe, 2020).

The need for technological innovation in charcoal production will be important and should be encouraged in areas where there is a significant demand for better quality (charcoal with a higher carbon content) for industrial uses. In many cities and towns, charcoal is needed for industrial and commercial uses as well as for domestic use as fuel (e.g., cooking and food processing) (Borowski, 2021). Charcoal production optimization in existing charcoal production techniques needs to be improved for both quality improvement and better production recoveries (Gebremariam & Marchetti, 2018). Wood charcoal makes a great fuel at home, and it can also be used to create bioenergy. Plus, even things like leaves and food scraps can be turned into charcoal. Wood charcoal is the most important commercial fuel derived from wood. Charcoal, a lightweight black carbon made from burning wood or other organic matter, falls into distinct types based on source and purpose: wood charcoal for fuel, industrial charcoal from coal or shells, and activated charcoal for purification. Wood charcoal is used as a domestic fuel for cooking and heating in many developing countries. Its advantages when used as a domestic fuel are that it produces less heat while burning, has a higher energy content per unit mass, can be easily transported and stored, and can be reused after cooking (Woolley et al., 2020). Charcoal production relies on thermochemical conversion through slow pyrolysis or carbonization, both under limited oxygen. Slow pyrolysis, in this method slowly heats biomass (mostly wood) in closed ovens to around 400-500°C, driving off volatile gases and leaving behind charcoal. It creates high-quality charcoal with high fixed carbon content.

Carbonization involves heating biomass in earth pits, kilns, or retorts to even higher temperatures (up to 800°C) with minimal air access. While faster than slow pyrolysis, it often yields lower quality charcoal with more ash and impurities. The specific process and temperature range used depends on the charcoal type being produced and the desired properties. Some methods also utilize byproducts like wood tar and pyroligneous acid. Wood is burned in sealed kilns or retorts, chambers with different gases and controlled and regulated airflow to create charcoal. By all methods, high-temperature heating transforms the wood into gases, a liquid tar combination and the well-established solid carbon compound known as charcoal (Zeng et al., 2017).

Despite the general trend away from using charcoal as a fuel for producing iron, some countries, most famously Sweden which has a large amount of native forest land and no coal, continued to use charcoal to produce the highest-quality iron and steel products well into the 20th century. Earlier this century, Sweden stopped producing charcoal iron due to a number of reasons including depleted forest supplies, higher labor expenses in rural areas, and easily available, cheap hydroelectric power. The second part of the country is where most developing markets with young steelmaking industries have discovered the advantages of melting iron in simple, reduced blast furnaces that burn charcoal as fuel (Cottrell, 2019). Waste wood has historically served as the primary raw material source for charcoal manufacture. A number of regularly wasted forestry and agricultural wastes appear to be potential major raw materials for the production of charcoal, considering that wood sources are frequently limited (Asare, Owusu & Gazo, 2022). Analyze wood species' charcoal quality, crowning the champion to guide lab selection and market decisions. (Kongprasert et al., 2019).

The characteristics of charcoal made from waste of wood species were being studied and the quantity and quality of the charcoal produced were evaluated. Ash content, moisture content, volatile matter, fixed carbon, and calorific value were collected from the selected species in order to determine the characteristics of charcoal yield. Eucalyptus charcoal stood out with the highest fixed carbon content (70%) and calorific value (22.5 MJ/kg), indicating its potential for generating more heat and lasting longer (Protásio et al., 2017). Charcoal's high volume and low value per unit of weight make it akin to transporting cotton balls versus diamonds. While a truckload of cotton balls might be less valuable than a handful of diamonds, the cotton balls would occupy significantly more space. For this reason, long-distance transportation may not be cost-effective without special containers or further compression to produce hardwood charcoal (Bao et al., 2019).

Charcoal yields can fluctuate dramatically due to seemingly minor variations in production. The pace of heating, the size and moisture content of the wood, and the precise temperature spectrum during the burn can all subtly influence the final output. Like a recipe with delicate measurements, even slight changes in these parameters can yield surprisingly different outcomes. Additionally, there are inevitable variations in fuel volume, moisture content, and energy value estimation (Motta et al., 2018). Charcoal flies under the domestic radar, possibly due to folks' thin wallets. To meet their domestic cooking fuel requirements, people frequently look for free supply sources. Such areas won't have any potential for charcoal production or trade so, it should not be promoted (Doggart & Meshack, 2017). Navigating the present crisis requires overcoming significant hurdles in importing LPG, from battling currency shortages and soaring fuel costs to confronting logistical bottlenecks and the looming risk of a burdened consumer and a shadowy black market. Alarming recent practices to fill domestic energy gaps call for immediate action. We must move beyond these shadowy solutions and embrace the sunshine of green energy options. The already identified environmentally friendly charcoal production offers a beacon of hope, paving the way for a sustainable future fuelled by responsibility and cleaner horizons.

Considering the fact that supplies of wood are often limited, a variety of agricultural and forestry residues that often remain unused appear to be potentially important raw materials for charcoal production. In 2020, Sri Lanka exported \$ 28.1M making it the 100th largest exporter of wood charcoal in the world (Cornot-Gandolphe, 2017). In the same year, wood charcoal was the 42nd most exported product in Sri Lanka. From tea wood in Middle East markets to Chinese logs crossing oceans, global wood destinations dance to the tune of species and shifting economic winds (Alvesdias et al., 2018). In order to ascertain the most appropriate strategy for sustainable and economical charcoal production, a thorough investigation should be carried out to compare the efficacy of teak root, off-cut, and Eucalyptus spp. waste timber materials for wood charcoal production. Additionally, the efficiency of various production methods should be assessed, and the cost-benefit ratio should be examined.

II. MATERIAL AND METHOD

A. Study Area

Sri Lanka State Timber Corporation (SLSTC) is a government-owned organization responsible for managing and controlling the country's timber resources. It was established in 1979 and operates under the Ministry of Mahaweli Development and Environment. SLSTC is responsible for logging, processing, and marketing of timber products, as well as reforestation and afforestation efforts in Sri Lanka. The corporation also manages and maintains several forest reserves and national parks in the country. This study was carried out at the State Timber Complex in Boossa (6°0”60"N 80°1'80"E) and the State Timber Corporation's Boralanda depot (6°4'24"N 80°9'28"E).

B. Waste Wood Samples Selection

The selection of waste wood samples for analysis depends on the specific research or study being conducted. However, there are a few general guidelines that should be followed when selecting waste wood samples such as representativeness in which the samples should represent the waste wood population being studied. This means that the samples should be randomly selected from different sources, such as different types of wood or different stages of decay. Storage and handling: the samples should be properly stored and handled to avoid contamination or degradation during transportation or storage. In this study, different wood waste materials were selected from the low-country dry zone and upcountry wet zone areas which are upstream of Sri Lanka with consideration above factors (Table 1). Three samples were gathered and replicated three times for the study's sample size. In the end, samples were burned and charcoal was gathered utilizing two different techniques, including the pit and barrel methods.

C. Collection of Waste Wood Samples

The samples should be collected using a method that is appropriate for specific research or study. For example, if the study is focused on the chemical composition of the waste wood, small core samples may be collected. If the study is focused on the physical properties of the waste wood, larger samples may be

Table 1. Selected waste offcut timber species for the experiments

No	Botanical name	Common name	Family
1.	*Azadirachta indica*	Margosa	Meliaceae
2.	*Artocarpus heterophyllus*	Jack	Moraceae
3.	*Eucalyptus grandis*	Grandis	Myrtaceae
4.	*Swietenia macrophylla*	Mahogany	Meliaceae
5.	*Tamarindus indica*	Tamarind	Fabaceae
6.	*Tectona grandis*	Teak	Lamiaceae
7.	*Terminelia arjuna*	Kumbuk	Combretaceae

Figure 1. Waste wood samples, A- Sample of *Eucalyptus* spp.; B- Sample of teak root; C- Sample of offcuts according to Table 1.

collected. By considering the above factors waste wood samples small sized for chemical composition and big offcuts were used to identify the physical factors were collected from the furniture factory in State Timber Complex Boossa and Boralanda Timber depot (Figure 1).

D. Charcoal Production Methods

I) Barrel method

The barrel method for charcoal production utilized two nested metal barrels. The larger barrel acted as a kiln, while the smaller held tightly packed hardwood. A fire in the larger barrel heated the wood within the smaller one to around 450-500°F (232-260°C) for several hours, driving out water and gases and leaving behind pure carbon to make the charcoal.

II) Pit method

In the pit method of charcoal production, a dug hole was lined with wood, ignited at one end, and then tightly sealed with layers of soil and leaves. This created a smothering environment where the wood slowly carbonized without burning away entirely. Monitoring for cracks and maintaining temperature through ventilation holes was crucial throughout the process, which can take a day or two. Once the smoke stopped and the pit cooled, the resulting charcoal was then unearthed.

E. Data Collection

All the produced charcoal from samples of *Eucalyptus* spp. teak root, and wood offcuts were tested by Industrial Technology Institute, Colombo 7, Sri Lanka. Data was collected on the moisture content, volatile matter, ash content, and fixed carbon, which were proximally resolved using the BS EN1860-2:2005 method and gross calorific value/kcal/kg using the ASTM D5865-13 test method (Benin et al., 2021).

III. RESULT AND DISCUSSION

A. The Yield of Charcoal

The physical properties of waste wood-charcoal production significantly varied among different species (Figure 3). Wood charcoal made from off-cuts of wood species recorded the highest yield of charcoal (28%) followed by Eucalyptus spp. (22%). Wood charcoal produced from Tectona grandis species showed the lowest yield of charcoal (14%). Pit and barrel processes can produce varying amounts of charcoal. Due to less regulated conditions, pit carbonization often has a lower yield, ranging from 15 to 25 percent of the initial biomass (Heidarinejad et al., 2020). The average yield of the three wood species (21.33%) is slightly higher than the average yield of pit carbonization (20%). Off-cuts of wood species (28%) significantly exceed the average pit carbonization yield. Tectona grandis (14%) is below the pit carbonization range, indicating it is less efficient even compared to the least efficient pit carbonization process. Better temperature control during barrel carbonization often results in increased yields of 20–30% of the original biomass (Heidarinejad et al., 2020). In this recent study, *Eucalyptus* spp. charcoal yield could reach 30%, Tectona grandis could reach 22%, and wood offcut obtained 35% of yield.

Figure 2. Charcoal production: A.Sketch of a barrel; B. Barrel method; C. Pit method

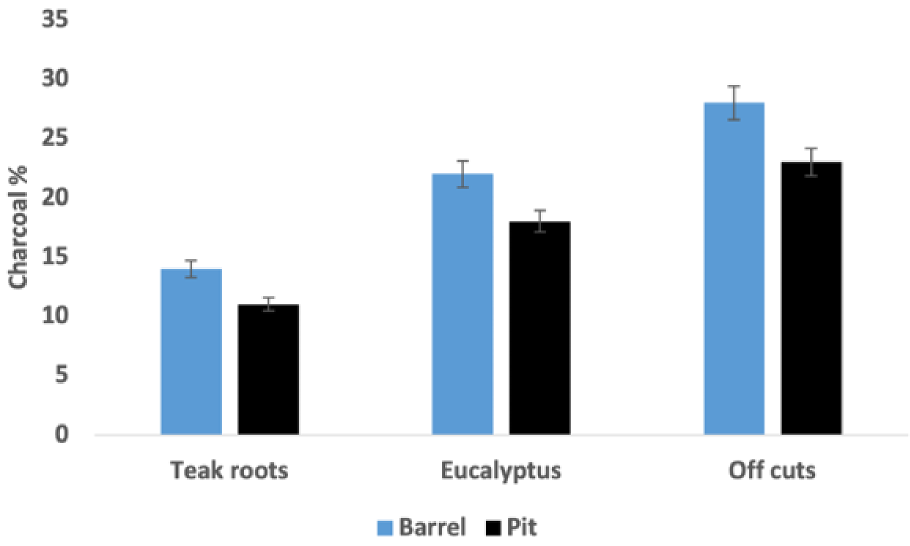

Figure 3. Charcoal yield of Barrel and Pit Method

Causal factors for low charcoal yield in barrel methods can include high moisture content, inadequate temperature control, limited oxygen supply, and wood density/species (Heidarinejad et al., 2020). The highest yield of charcoal production was given by offcuts due to the use of various high-density timber species such as *Azadirachta indica*, *Artocarpus heterophyllus*, *Swietenia macrophylla*, *Tamarindus indica*, *Tectona grandis*, and *Terminalia arjuna* (Hashim et al., 2015). It's also worth noting that the yield will also vary based on the type of wood used for example Teak roots charcoal production is low due to suboptimal. Hardwoods such as oak, hickory, and beech typically have higher charcoal yields than softwoods such as pine or spruce. Additionally, the moisture content of the wood will also affect the charcoal yield, with lower moisture content resulting in higher yields (Heidarinejad et al., 2020). The yield of wood-charcoal varies greatly depending on the species, with off-cuts offering the largest output. Because of the less controlled environment, pit carbonisation yields are typically lower and more variable. This emphasises the value of choosing particular wood species and maybe more controlled methods like barrel carbonisation for higher and more consistent yields.

B. Moisture Content

As seen in Figure 4, the moisture content of the resulting wood charcoal differed significantly between the samples. Charcoal made from Eucalyptus species had the highest moisture level (7%) whereas charcoal made from wood offcuts had the lowest moisture content (5%). The moisture percentage of charcoal derived from the wood species Tectona grandis was found to be 6%.

It is important to note that the moisture content in charcoal should be as low as possible, as high moisture content can lead to problems such as spontaneous combustion, decreased energy density, and difficulty to light (Darmstadt et al., 2000). It is also worth noting that the moisture content of charcoal can vary depending on the method of production and the type of wood used. Charcoal made from freshly cut wood or wood with a high moisture content will have a higher moisture content than charcoal made from seasoned wood or wood with a lower moisture content (Danish and Ahmad, 2018).

This is because the high content of moisture makes fine wood charcoal and lowers its calorific value (Yaseen et al., 2020). Open drying in the pit process might reduce the moisture content

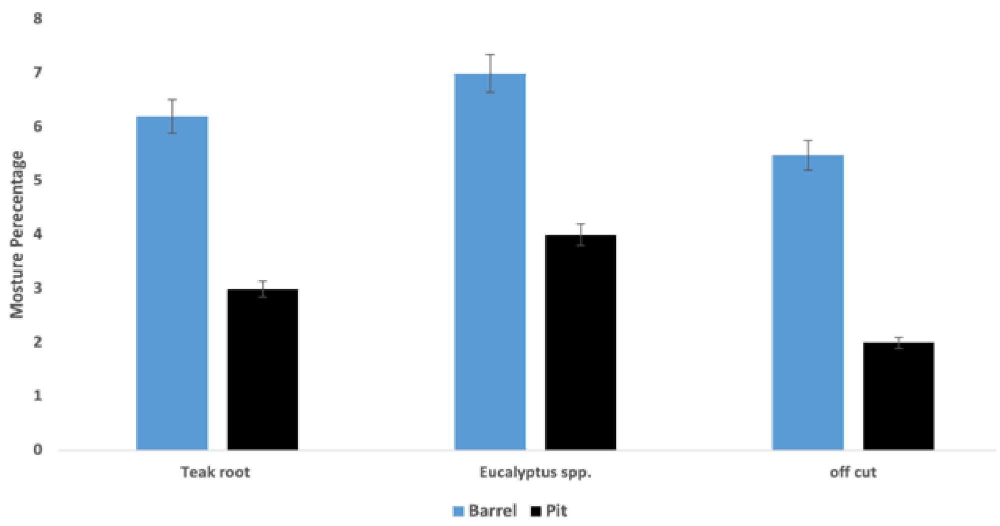

Figure 4. Moisture content percentage in the charcoal produced by barrel and pit method

of *Eucalyptus* charcoal from 7% to somewhere between 4% (Darmstadt et al., 2000). Similarly, *Tectona grandis* charcoal could reach a range of 3% moisture content, and wood offcuts might have their moisture level drop to as low as 2%. The moisture content values of wood charcoal manufactured from various wood species utilized for this study were within the acceptable criteria established by the FAO (1985) which stated that the highest limit for moisture content is 7% (FAO 1985). The average yield of the three wood species (21.33%) being slightly higher than the pit carbonization yield (20%) suggests that, on average, specific wood species can be slightly more efficient. Off-cuts of wood species (28%) provide a significantly higher yield, making them highly efficient. *Tectona grandis* (14%), however, falls below even the minimum efficiency of pit carbonization. The reduction in moisture content through open drying in the pit process further enhances the quality of the charcoal, making it more energy-dense and efficient. Therefore, selecting appropriate wood species and managing moisture content are crucial factors in optimizing charcoal production.

The moisture percentage in the pit and barrel method was not a fixed value, but rather a range that depended on the specific type of wood charcoal and the drying conditions. However, as a general rule of thumb, the moisture content of wood charcoal produced using the pit and barrel method is typically between 1-5% (Darmstadt et al., 2000). This is significantly lower than the moisture content of fresh wood, which can be as high as 50% (Darmstadt et al., 2000).

C. The content of Volatile Matter

The wood charcoal from *Eucalyptus* spp. had the highest volatile matter level at 17%, which was almost equal to *Tectona grandis*'s volatile matter content of 16.5%. On the other hand, Figure 5 shows that charcoal made from wood offcuts had the lowest volatile matter level, at 14%. Charcoal made from wood offcuts, *Tectona grandis*, and *Eucalyptus* species had a volatile matter percentage of 12%, 14%, and 15% in the pit method, respectively. Notably, charcoal made by the pit and barrel techniques might have different volatile matter contents. According to FAO (1985), wood charcoal can have a volatile matter percentage of anywhere from 5% to 40%. (FAO 1985). *Eucalyptus* spp. has the highest volatile matter content at 17%, closely followed by *Tectona grandis* at 16.5%. Wood offcuts have the lowest volatile matter content at 14%.

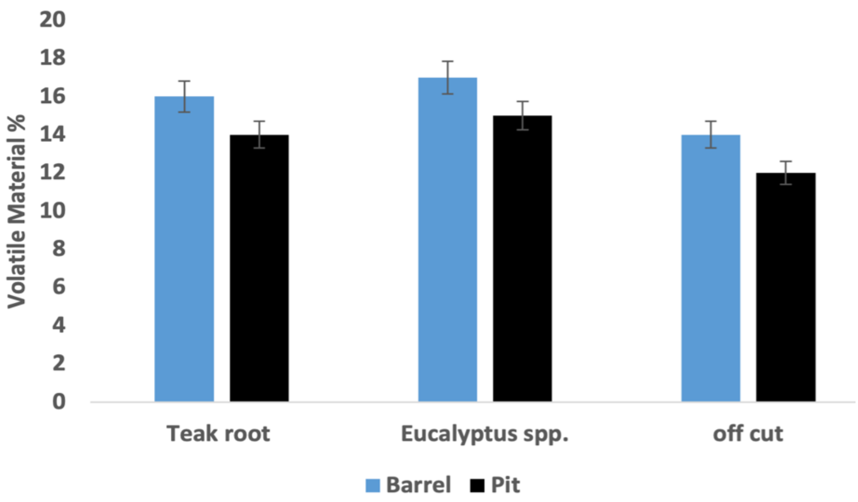

Figure 5. Volatile matter content of the charcoal in the barrel and pit method

The pit method generally reduces volatile matter content in all wood species. Wood offcuts show a reduction from 14% to 12% (2% decrease). *Tectona grandis* shows a reduction from 16.5% to 14% (2.5% decrease). Eucalyptus spp. shows a reduction from 17% to 15% (2% decrease).

Charcoal made from offcuts, or small pieces of wood that are left over from other woodworking processes, can have a higher volatile matter content than charcoal made from larger pieces of wood. Volatile matter is the portion of charcoal that is composed of gases and other volatile compounds that are released during the carbonization process. Offcuts usually have a higher volatile matter content due to their small size which causes an increase in the ratio of surface area to volume, leading to higher evaporation of volatile compounds. This can result in charcoal with a lower energy density and higher ash content. Additionally, offcuts may have a higher moisture content which also results in higher volatile matter(Ge et al., 2023).

It's worth noting that the volatile matter content of charcoal can also be affected by the method of production, with traditional pit methods generally producing charcoal with a higher volatile matter content than more modern methods such as retort kilns. Charcoal with higher volatile matter content is not always a disadvantage, as it can be used in certain industrial applications such as activated carbon production where the presence of volatile matter can be beneficial (Kumar et al., 2021).

The components of the biomass that are emitted as gases during carbonization are referred to as volatile matter. The charcoal produced by the pit method frequently has a greater volatile matter concentration due to slower carbonization and lower temperature control. As a result of superior temperature control, the barrel process typically results in charcoal that contains less volatile materials (Deenik, 2011). Regarding wood charcoal quality, low levels of volatile matter in wood charcoal are associated with higher lignin levels and lower extractive levels in the wood species (Massuque et al., 2021). The high value of the volatile matter in wood charcoal makes it light easily but may burn with a little smoke (Deenik, 2011). Charcoal with lower volatility is hard to ignite and burn cleanly. Moreover, higher volatile matter in wood charcoal is favored for some uses like barbecue, while other uses like purification of chemicals and metal production need wood charcoal with a lower content of volatile matter. Good commercial wood charcoal has a net content of volatile matter (moisture-free) around 30%. High-volatile wood (charcoal) is normally hard (Ahamad et al., 2020). The volatile matter other than water in charcoal comprises all those liquid and tarry residues not fully forced off in the carbonization process. If the time and temperature of carbonization increase, then the volatile matter content is low (Üner & Bayrak, 2018).

D. Ash Content

The ash contents were significantly different among the produced wood charcoals (Figure 6). In the barrel method, wood-charcoal of *Eucalyptus* spp had the highest value (13%), while wood-charcoal of *Tectona grandis* and offcuts showed low ash content values, each was 12% and 11%, respectively. In the pit method ash content was higher than in the barrel method which was 17.3% and was observed in *Eucalyptus* spp Claims that the presence of high mineral composition in wood is expensive because the minerals do not degrade after carbonization and remains in charcoal as undesirable residues that also contribute to a reduction in the calorific value of charcoal (Ahmad et al., 2020). The ash content of wood charcoal can vary from around 0.3 percent to 16 percent or more, depending on the wood species used to make the charcoal. High-quality wood charcoal has a content of about 3% (FAO, 1985). Fine wood charcoal may have a very high ash content; buyers naturally suspect fine wood charcoal, and it is unfortunately difficult to sell and use (Ahmad et al., 2020). Statistically, *Eucalyptus* spp. has the highest ash content, making it less desirable for charcoal production due to lower calorific value and higher residues. The barrel method is more effective in reducing ash content compared to the pit method, particularly for *Eucalyptus* spp. Wood offcuts are the best option among the species studied, as they produce charcoal with the lowest ash content, indicating higher quality and efficiency. The pit method results in significantly higher ash content (4.3% increase) compared to the barrel method.

Charcoal made in a pit or a barrel might have varying amounts of ash. Due to exposure to outside pollutants, the open-air carbonization process used in the pit method frequently produces greater ash contents. The barrel method, on the other hand, can provide charcoal with a lower ash level due to its regulated environment. Ash content in both techniques can be reduced through cautious handling and good feedstock selection. The ash content of charcoal typically ranges from 1-5%. The process of making charcoal involves heating wood in the absence of oxygen, which causes the wood to release its moisture, gases, volatile compounds, and mineral matter that don't burn and remain as ash. Factors that can affect ash

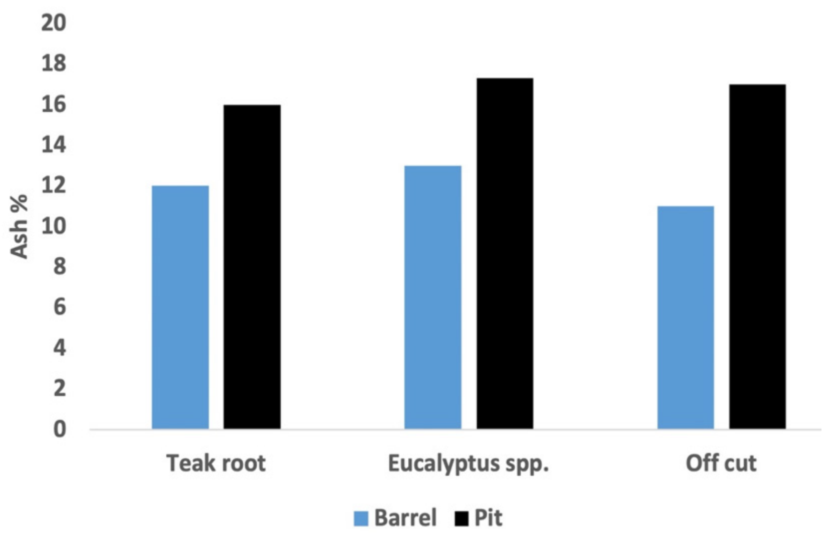

Figure 6. Ash content percentage in the charcoal produced by the barrel and pit method

content in charcoal include the type of wood used, the moisture content of the wood, and the method of charcoal production. Hardwoods such as oak, hickory, and beech typically have lower ash content than softwoods such as pine or spruce. Additionally, the moisture content of the wood will also affect the ash content, with lower moisture content resulting in lower ash content.

Charcoal made from offcuts also tends to have higher ash content. The ash content of charcoal can be important in certain applications such as metallurgy and ceramics where a low ash content is desirable, while in others like agriculture, the presence of certain mineral elements can be beneficial (Ramos et al., 2019).

E. Content of Fixed Carbon

There was a significant variance in the content of fixed carbon among the charcoal samples. In the barrel method, the highest fixed carbon was found in *Eucalyptus* spp. (82.7%), while the lowest was noticed in *Tectona grandis* (67.8%). Charcoal produced by offcuts showed a fixed carbon content of 78.8% (Figure 7). Wood charcoal has a fixed carbon content that ranges from a low of 50% to a high of roughly 95% (FAO 1985). Furthermore by the pit method of carbonization practices, *Eucalyptus* spp. 88.8%; *Tectona grandis*: 73.5%; and Offcuts: 84.7% were observed. Statistically, *Eucalyptus* spp. demonstrates the highest fixed carbon content, making it the best choice for efficient and high-quality charcoal production. The pit method further enhances the fixed carbon content for all species, with *Eucalyptus* spp. achieving the highest increase. *Tectona grandis* consistently shows the lowest fixed carbon content, indicating its lower suitability for high-quality charcoal production. The choice of wood species and carbonization method significantly impacts the fixed carbon content and, consequently, the quality and economic value of the charcoal produced. In determining the quality of the charcoal, high grades of fixed carbon and high grades of lignin combine with low grades of extractives and holocellulose in wood to provide better chemical attributes of charcoal (Do Rosário et al., 2020). By altering the carbonizing process's temperature and duration, the amount of fixed carbon might be adjusted. This method reduces the production of charcoal while simultaneously increasing the fixed carbon content of the wood charcoal (Ren et al., 2020).

The type of biomass utilized and the carbonization process are two variables that can affect the fixed carbon content of charcoal made using the pit and barrel method. However,

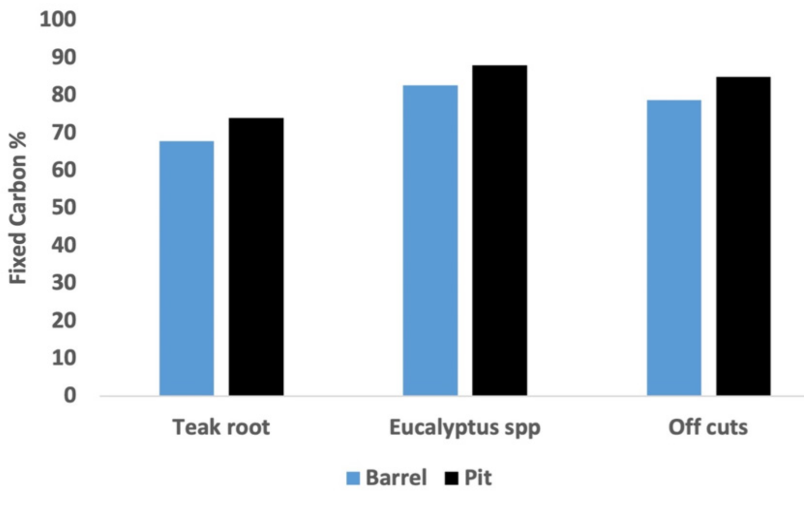

Figure 7. Fixed carbon content in the charcoals produced by the barrel and pit method

compared to charcoal generated using the barrel method, charcoal produced using the pit method may often have a lower fixed carbon content. The barrel method tends to encourage more carbonization and higher fixed carbon content due to its controlled temperature and oxygen supply. The fixed carbon content of charcoal is typically between 60-80%. Fixed carbon is the portion of the charcoal that remains after the volatile matter (gases and other volatile compounds) has been released during the carbonization process. It is called "fixed" because it is not released when the charcoal is heated. Fixed carbon content is an important characteristic of charcoal as it is directly related to the heating value of charcoal, meaning that charcoal with higher fixed carbon content will have a higher energy density and will produce more heat when burned (Ajimotokan et al., 2019).

The type of wood used, the moisture content of the wood, and the method used to produce the charcoal all affect its fixed carbon content. Hardwoods, such as oak, hickory, and beech, usually have a higher fixed carbon content than softwoods, like spruce or pine. Moreover, a higher fixed carbon content is generally correlated with lower wood moisture levels. Notably, the method of production can also affect the fixed carbon concentration; charcoal produced using conventional pit methods frequently has a lower fixed carbon percentage than charcoal produced using more contemporary techniques like retort kilns. Furthermore, charcoal made from leftovers often has a lower fixed carbon concentration.

F. Calorific Value

The calorific values of the charcoal were significantly different between different types of wood and between different producing methods with $P<0.05$ (Figure 8). The highest calorific value was noted in charcoal produced from *Tectona grandis* wood (7047 kcal/kg), followed by charcoal produced from *Eucalyptus* spp. (6848 kcal/kg) and wood offcuts (6755 kcal/kg0). However, although wood charcoal of *Tectona grandis* showed the highest calorific value, it had a higher production cost. The calorific values of charcoal produced by pit carbonization practices were 88.8%, 73.5%, and 84.7% each for *Eucalyptus* spp. *Tectona grandis*, and wood offcuts, respectively.

Wood offcuts had the lowest calorific values which presumably was due to their smaller size. The offcuts were mostly composed of roots and large root pieces were difficult to turn into charcoal, therefore, those pieces were cut into small pieces prior to the carbonization process. Although offcuts had the lowest calorific value,

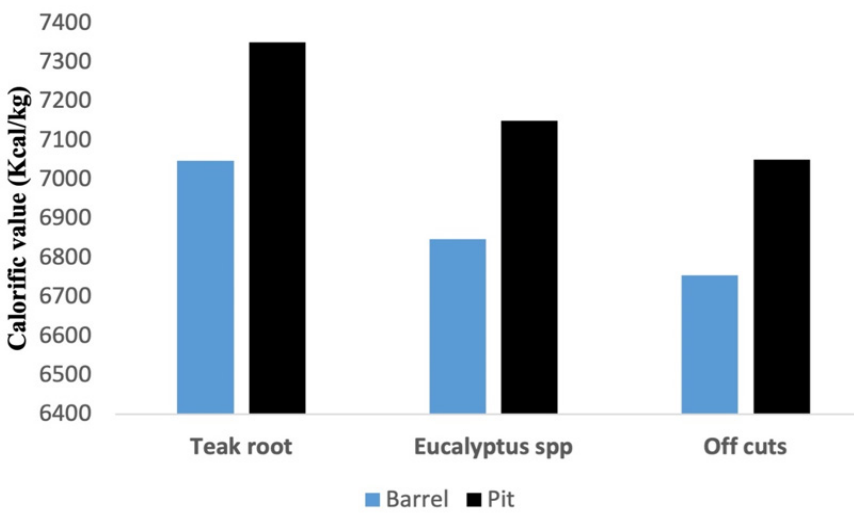

Figure 8. Calorific value of charcoals made by barrel and pit method

the chemical properties of the resulted charcoal were superior to those of other species, it also had a higher production percentage, the lowest moisture content, and the highest fixed carbon value.

The calorific value of charcoals made from different types of wood can vary depending on the specific type of wood used and the method of charcoal production. Hardwoods such as oak, hickory, and beech often have higher calorific values than softwoods like pine or spruce. This is explained by hardwoods' higher density, lower moisture content, and higher fixed carbon content, all of which add to their higher calorific value.

For example, charcoal made from oak has a calorific value of around 29,000-30,000 kcal/kg, while charcoal made from pine has a calorific value of around 25,000-27,000 kcal/kg (Qian et al., 2020). The calorific value of charcoal can also be affected by the method of production utilising more contemporary techniques, including retort kilns, creating charcoal with a higher calorific value than old pit processes.. Charcoal made from offcuts also tends to have lower calorific value. The calorific value of charcoal is important because it determines the amount of energy that can be released when the charcoal is burned. It is measured in units of energy per unit of mass and is often expressed in units such as kilocalories per kilogram (kcal/kg) or joules per kilogram (J/kg).

G. Effective Method of Charcoal Production

In the barrel method, the highest cost of wood charcoal production was from the root of *Tectona grandis* and the lowest was for *Eucalyptus* spp.

The yields and costs of producing charcoal varied significantly, according to the study. A 28% yield was obtained from the production of charcoal, and the cost of production was found to be minimal. There were notable variations in the amount of charcoal produced by the several wood species that were investigated.

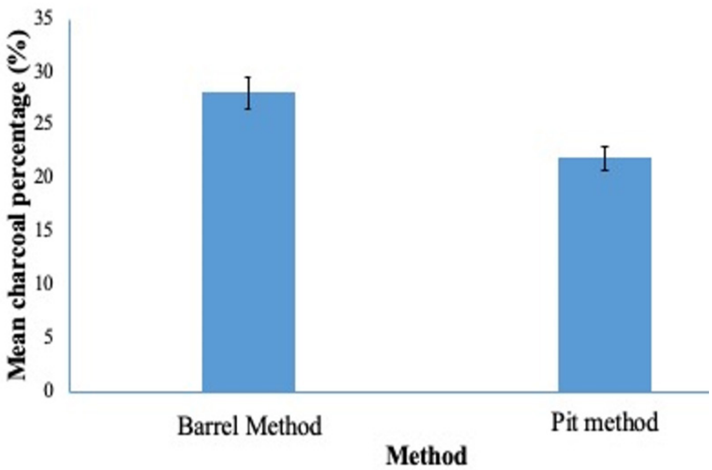

Figure 9. The yield of charcoal produced by the barrel and pit method

Table 2. Cost-effective analysis of charcoal production in barrel method

	Teak	mix-wood Offcuts	Eucalyptus offcuts
Production of Charcoal			
Weight (Kg)	896	523	1000
Partially burned charcoal (Kg)	20	12	35
Total Charcoal Production (Kg)	129	89	89

Table 2. Contunued

	Teak	mix-wood Offcuts	Eucalyptus offcuts
Cost			
Teak root transport/loading and unloading	$58.14		
Chain saw fuel	$05.81		
Chain saw 02	$20.34		
Chain saw operator hire	$08.72		
Row material		$02.90	$05.81
Labour cost	$15.11	$07.56	$11.34
Other expenses	$05.81	$05.81	$05.81
Total Cost	$113.95	$16.28	$22.96
Cost for 1Kg of charcoals (without packing cost)	$00.83	$ 0.17	$ 0.1
Cost in $ (1$=344 Rupees)	$0.83	$ 0.17	$ 0.1

Overall, these results show how economical and efficient the production process was, and they also show how the type of wood used can affect efficiency differently.

IV. CONCLUSION

For optimal charcoal production, selecting appropriate wood species and carbonization methods is crucial. *Eucalyptus* spp. and wood offcuts are preferable due to their higher fixed carbon content and yield, respectively. The pit method enhances fixed carbon content but requires careful management to control ash content. These findings guide the selection and processing of biomass for efficient, high-quality charcoal production, balancing yield, fuel quality, and economic value.

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REVITALIZING FOREST MANAGEMENT IN INDONESIAN FOREST INDUSTRY POST-COVID-19: EXPECTATIONS FROM YOUNG FORESTERS (A CASE STUDY FROM UNIVERSITY STUDENTS)

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REVITALIZING FOREST MANAGEMENT IN INDONESIAN FOREST INDUSTRY POST-COVID-19: EXPECTATIONS FROM YOUNG FORESTERS (A CASE STUDY FROM UNIVERSITY STUDENTS). The global health emergency triggered by COVID-19 has had a significant impact on Indonesia's forestry industry. This study investigates the expectations of young foresters regarding the post-pandemic landscape, exploring various aspects such as industry performance, focus, worker protection, global strategies, and personal views on the industry's future. In conjunction with descriptive statistics, word cloud analysis was employed to identify salient issues drawing substantial attention. Through purposive sampling at a leading forestry university in Indonesia, the study reveals that young foresters perceive the transition towards developing industries based on non-timber forest products and environmental services as potential areas of growth. However, they acknowledge that the timber-based industry has historically been the backbone of Indonesia's forest industry and is likely to maintain its significance as forest management trends toward plantation forestry. Additionally, the study demonstrates the enduring appeal of the forestry sector to the younger generation, positioning it as a valuable entrepreneurial field.

Keywords: COVID-19, forestry business, forest commodity, non-timber forest products, young forester

REVITALISASI INDUSTRI KEHUTANAN INDONESIA PASCA COVID-19: HARAPAN DARI RIMBAWAN MUDA (STUDI KASUS DARI KALANGAN MAHASISWA). Darurat kesehatan global yang dipicu oleh COVID-19 telah memberikan dampak signifikan pada industri kehutanan Indonesia. Penelitian ini menyelidiki harapan para rimbawan muda terkait lanskap pasca pandemi, mengeksplorasi berbagai aspek seperti kinerja industri, fokus, perlindungan pekerja, strategi global, dan pandangan terhadap masa depan industri kehutanan di Indonesia. Selain statistik deskriptif, analisis word cloud digunakan untuk mengidentifikasi isu-isu utama yang menarik perhatian. Melalui pengambilan contoh secara sengaja (purposive sampling) di sebuah universitas kehutanan terkemuka di Indonesia, penelitian ini mengungkap bahwa para rimbawan muda melihat transisi menuju pengembangan industri berbasis hasil hutan bukan kayu dan jasa lingkungan sebagai area potensial pertumbuhan. Namun, mereka juga menyadari bahwa industri berbasis kayu secara historis telah menjadi tulang punggung industri kehutanan Indonesia dan kemungkinan akan tetap memiliki signifikansi seiring tren pengelolaan hutan menuju hutan tanaman. Selain itu, penelitian ini menunjukkan bahwa sektor kehutanan tetap menjadi daya tarik yang berkelanjutan bagi generasi muda, menjadikannya sebagai bidang wirausaha yang berpotensi.

Kata kunci: Rural, eco-rural tourism, polarisasi, masyarakat lokal

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I. INTRODUCTION

The unprecedented COVID-19 pandemic has become a public health emergency of international concern (Attah, 2021). The virus can spread easily and cause fatal losses, not only for the sufferers but also for the economic stability of a country and ultimately the global order, forcing countries to implement various mitigation approaches depending on the level of virus spread, the capacity of the healthcare system, government policies, and local situations. The implementation of health protocols, lockdowns, and travel bans in high-risk areas are the most commonly adopted strategies (Kaimann and Tanneberg, 2021). As a result, the movement of people is affected, which harms almost all sectors. The BPS survey results (BPS, 2021) indicate that only about 50% of companies in the agriculture, services, and manufacturing sectors in Indonesia (mostly small and non-corporate businesses) remained operational during the pandemic. The various social restrictions imposed have an impact on the forestry sector in terms of social organization, economics, and the environment. In terms of social organization, the COVID-19 pandemic has been shown to decrease employees' perceptions of organizational politics (Larasatie et al., 2021). In the context of the environment, Attah (2022) reported that COVID-19 hampers sustainable forest management, forest protection, afforestation, and conservation efforts in all sub-regions of Africa. He highlights a significant rise in the risk of biodiversity loss in Africa's forested areas since the beginning of the pandemic. In Nepal, COVID-19 has severely affected nature-based tourism, a crucial part of the national economy (Sah et al., 2020; Maraseni et al., 2022). Similarly, East and Southern Africa, known for its ecotourism industry, has been affected (Attah, 2022). In terms of the economy, Vietnam has experienced massive cuts in production and a significant decrease in export supply chains in the wood processing sector (Vietnamnet, 2020). As a result of the COVID-19 pandemic's economic pressure on Indonesia, there has been an increase in illegal logging cases in addition to a significant decline in export performance (reaching 8.3% in January–May 2020, according to KLHK, 2020) (Golar et al., 2020). This increase in illegal logging has also been observed in almost all regions of Africa (Attah, 2022).

COVID-19 has not only had negative impacts. The policy of limiting human activities during the pandemic and reducing economic activities, including the industrial sector, provides the potential for temporary restoration of the Earth's ecosystem. This includes significant improvements in global air quality (Venter et al., 2020; Silva et al., 2022) and water quality (Patel et al., 2020; Yunus et al., 2020).

These studies have provided insights into the dynamics resulting from the pandemic. COVID-19 can potentially drive dynamics in the forestry business in unexpected directions (Sah et al., 2020; Maraseni et al., 2022). The industry's emphasis can change from being primarily on timber or non-timber forest products to relying on environmental services, or vice versa (Laudari et al., 2021). Although these dynamics may be temporary, if the direction of the forestry business offers long-term profit potential, the trends need to be corrected and maintained. Therefore, a broader analysis is needed to determine the direction of forestry sector development in Indonesia. This analysis can be based on the dynamics of the global forestry business, assessments from forestry business players, and insights from knowledgeable observers in the forestry sector.

Forestry business activities involve the production, purchase, sale, and exchange of goods and services, either by individuals or companies (Brandt & Buckley, 2018; Hurmekoski et al., 2018). The purpose of business is to generate profit and provide goods or services to the community. On the one hand, Indonesia's vast tropical forests should enable the forestry business to make significant contributions to the country in terms of social, economic, and ecological aspects. This means that the forestry business should not solely focus on profit, goods, and services but also prioritize forest sustainability as its primary goal (Golar et al., 2020; Martinho et al., 2020; Marasenin et al., 2022). Imbalanced forest utilization and sustainability will lead to various problems, including social, economic, and ecological issues, which will ultimately hinder the achievement of Sustainable Development Goals (Baumgartner, 2019).

While various studies have explored consumer behavior during the pandemic, particularly in industries such as cosmetics, household products, textiles and apparel, and consumer electronics (Jan et al., 2022), there is still limited research on the thoughts and opinions regarding the direction of the forestry business post-COVID-19, especially from young foresters in the field of forestry science. BP2 (2022) notes that the age group of 20–24 is the largest among all age categories, totalling 22.6 million. This group is characterized as often being critical, having diverse ideas, and possessing skills that will support them in playing a significant role in forest governance (Robson et al., 2020), a role projected to become more prominent in the coming years. Therefore, gaining a better understanding of the aspirations of young foresters positions us more broadly in formulating strategies, policies, and practices that align with the evolving challenges of the future (Aquino-Moreschi, 2016). The thoughts and views of these young foresters, representing expectations for the forestry business in Indonesia after the COVID-19 pandemic, provide valuable insights for various stakeholders, including governments, regulatory bodies, practitioners, academia, industry, and researchers, in formulating the direction of forestry business development in Indonesia post-COVID-19.

II. MATERIAL AND METHOD

The data used in this study are the opinions of young foresters (students of the Faculty of Forestry, IPB Class of 2018). Data collection and analysis were conducted from March to November 2022. Given the conditions of offline activity restrictions, the research was conducted in a hybrid manner, a combination of offline and online (using Google Forms, which were then verified through direct discussions

Table 1. Results of validity test with SPSS

Aspects	Item statements**	Corrected Item Total Correlation	r-table	Validity*
1. Expectations for the performance of Indonesia's forestry business by commodity form/type category	Statement 1.2	0.604	0.217	V
	Statement 1.3	0.408	0.217	V
	Statement 1.5	0.483	0.217	V
	Statement 1.6	0.726	0.217	V
	Statement 1.7	0.667	0.217	V
2. Post-pandemic outlook/forecast of upstream and downstream forestry industry trends	Statement 2.1	0.539	0.217	V
	Statement 2.2	0.473	0.217	V
	Statement 2.3	0.562	0.217	V
	Statement 2.4	0.586	0.217	V
	Statement 2.5	0.560	0.217	V
	Statement 2.6	0.619	0.217	V
	Statement 2.7	0.530	0.217	V
	Statement 2.8	0.642	0.217	V
	Statement 2.9	0.585	0.217	V

Table 1. Contunued

Aspects	Item statements**	Corrected Item Total Correlation	r-table	Validity*
3. Expectations concerning the protection of occupational safety and health of those working in the forestry industry	Statement 3.1	0.601	0.217	V
	Statement 3.2	0.670	0.217	V
	Statement 3.3	0.811	0.217	V
	Statement 3.4	0.381	0.217	V
	Statement 3.5	0.565	0.217	V
	Statement 3.6	0.834	0.217	V
	Statement 3.7	0.803	0.217	V
	Statement 3.8	0.867	0.217	V
	Statement 3.9	0.803	0.217	V
4. Strategies for maintaining/improving the efficacy of the forestry industry	Statement 4.1	0.785	0.217	V
	Statement 4.2	0.797	0.217	V
	Statement 4.3	0.788	0.217	V
	Statement 4.4	0.841	0.217	V
	Statement 4.5	0.835	0.217	V
5. Personal insight on the state of the Indonesian forestry industry in the future	Statement 5.1	0.567	0.217	V
	Statement 5.2	0.747	0.217	V
	Statement 5.3	0.686	0.217	V
	Statement 5.4	0.639	0.217	V
	Statement 5.5	0.577	0.217	V
	Statement 5.6	0.428	0.217	V

Note: *) Only valid items presented; ** The question descriptions are as listed in Figure 1-7.

Table 2. Results of reliability test with SPSS

	Aspects*)	Cronbach's alpha	N of items
1.	Performance of Indonesia's forestry industry by commodity form/ type category	0.445	5
2.	The focus of Indonesia's forestry industry from the category type between upstream and downstream	0.734	9
3.	Protection for forestry workers	0.847	9
4.	Strategies to maintain or improve the performance of the forestry sector at the global level	0.867	5
5.	Personal outlook on the future of forestry	0.668	6

Note: *) Only valid items presented

with respondents). The number of participants (80 students, 41 males, and 39 females) was determined based on the well-known Slovin method. The sampling method used was non-probability sampling with the purposive sampling technique. This sampling is used so that the criteria for participant characteristics can be adjusted so that the selected participants can better represent the population criteria.

In this study, respondents were asked to reflect on their expectations of various areas, both with open and closed questions, through an attitude scale (5 scales, 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree; adopting the Likert scale). The items were divided into five categories: 1) respondents' views on the performance of the Indonesian forestry industry based on the category of commodity form or type (5 items); 2) the focus of the Indonesian forestry industry from the category type between upstream and downstream (9 items); 3) protection for forestry workers (9 items); 4) strategies to maintain or improve forestry sector performance at the global level (5 items); and 5) personal views on the future of the forestry business (6 items). To ascertain the description or distribution of the sample or population data as it is, the survey data underwent additional descriptive analysis.

Before the instrument was used, validity (content validity) and reliability tests using SPSS were conducted on the questionnaire (Table 1, Table 2). The validity test is conducted to measure whether a questionnaire is valid. The validity test used in the study was the Pearson's product moment correlation technique with the criteria of r count > r table (0.217). The questions in the questionnaire are designed to represent the variables that reflect the expectations of young foresters regarding the measured aspects. The reliability test was conducted to ensure the consistency of the measuring instrument when measuring similar symptoms. In this study, we used a criterion (>0.4) based on the opinions of Griethuijsen et al. (2014).

In addition, the participants were also asked to express their opinions in the form of a short essay regarding four issues, namely: post-COVID-19 flagship environmental service commodities, forest products requiring optimization in downstream industries, performance of non-timber forest products (NTFPs) commodity products, and environmental service commodity products that are perceived to require diversification. The opinions expressed in textual form are then summarized using word clouds to facilitate easy comprehension for the reader.

III. RESULT AND DISCUSSION

A. Expectations for the performance of Indonesia's forestry business by commodity form or type category

The young foresters' expectations of forest industry performance (production) by commodity category show an optimistic view of timber, NTFPs, and environmental services (Figure 1).

Figure 1. The young foresters' expectations of the performance of the forestry industry after the COVID-19 pandemic. Notes: 1.2 = The performance of the timber commodity-based forestry industry will increase; 1.3: The performance of the NTFP commodity-based forestry industry will increase; 1.5 = the performance of the timber commodity-based forestry industry will be higher than the performance of the NTFP commodity-based forestry industry; 1.6 = the performance of the timber commodity-based forestry industry will be higher than the performance of the environmental services commodity-based forestry industry; 1.7 = The performance of the NTFP commodity-based forestry industry will be higher than the performance of the environmental services commodity-based forestry industry

Young foresters believe that the NTFP commodity industry will be the main support for the forestry industry in the future. This is in line with the fact that some NTFPs are one of the mainstays of the community during a pandemic because of their properties, which are believed to be able to provide additional endurance (Al-Kuraishy et al., 2022). However, although there is a tendency for NTFP commodities to shift the timber industry's significant position, which has long served as the foundation of Indonesia's forestry industry, it appears to play a role as well.

The young forester's view on the prospect of environmental services is not clearly illustrated in this study; however, the word cloud analysis shows that nature tourism (ecotourism) will be the backbone of the environmental services-

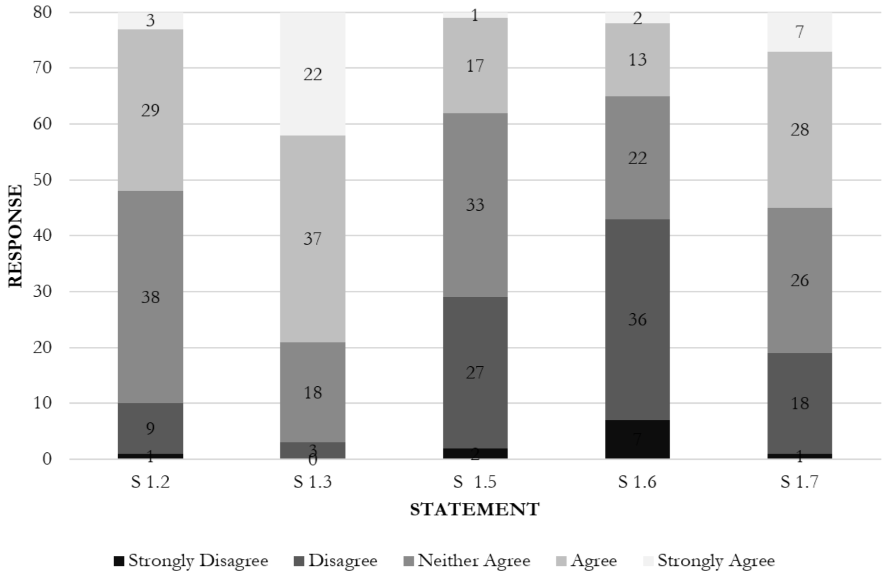

Figure 1. The young foresters' expectations of the performance of the forestry industry after the COVID-19 pandemic.

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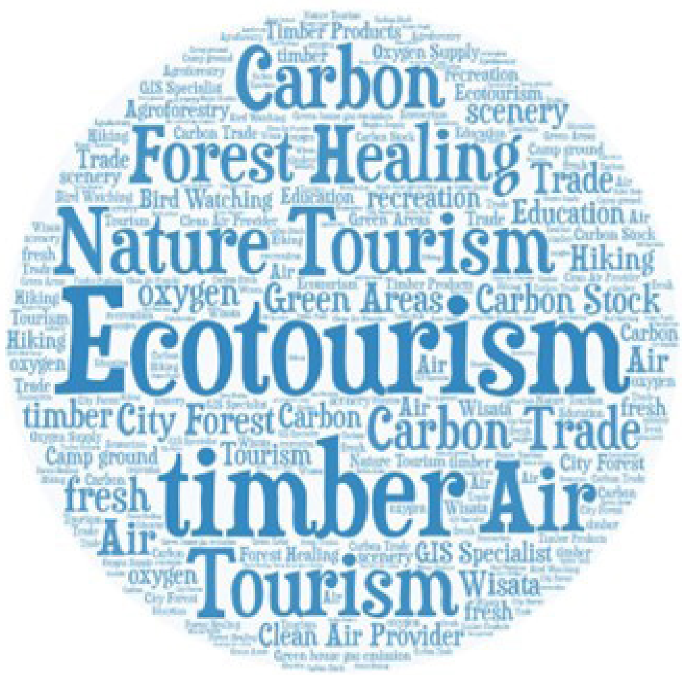

Figure 2. Post-COVID-19 flagship environmental service commodities

based forestry industry. The most frequently mentioned keywords are "ecotourism," "nature tourism," "forest," and "forest healing" (Figure 2). This optimistic view is in line with the Indonesian Central Bureau of Statistics (BPS) data (2022), which shows an increase in the number of tourists by 616.40% in the January–May 2022 Post-pandemic, outdoor activities in nature-related locations, both for sports and recreation purposes, seem to be an inevitable trend (Hedenborg et al., 2022).

Although the performance of the forestry industry in environmental services commodities has increased, in the future, the performance of the NTFP commodity industry will still be considered higher than environmental services and timber after the COVID-19 pandemic. Meanwhile, the performance of the environmental services and NTFP industries is predicted to exceed that of the timber industry. Mutaqin et al. (2022) noted that the COVID-19 pandemic caused a decrease in global demand for wood and processed wood from Indonesia, thus hampering the wood export chain to the global market.

B. Post-COVID-19 flagship environmental service commodities

The young forester expressed an optimistic outlook regarding the future roles of both the upstream and downstream industries. They referred to log and NTFP as commodities in the upstream industry, while pulp, composite, and furniture were considered commodities in the downstream industry (Figure 3). A more detailed look at the timber industry (Figure 4) indicates that young foresters are quite optimistic that plantation forests will

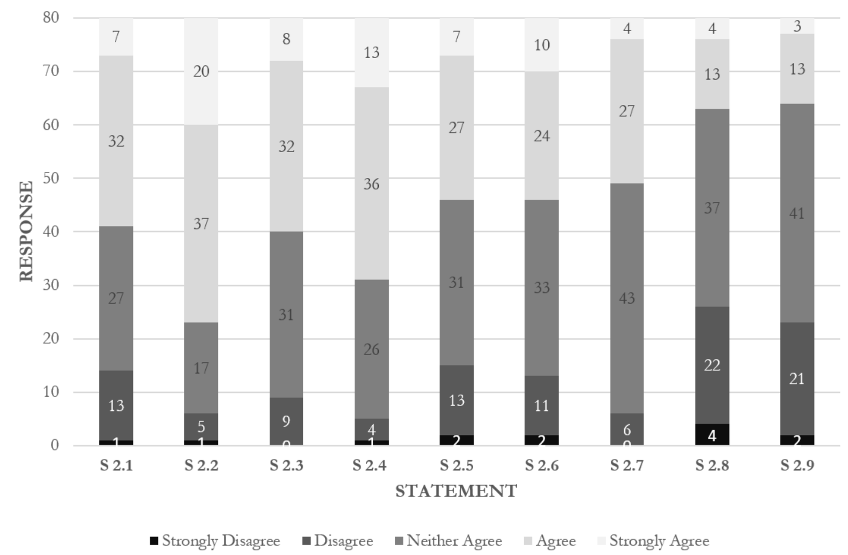

Figure 3. Post-pandemic outlook and forecast of upstream and downstream forestry industry trends

Notes: 2.1 = Upstream businesses (those producing timber and NTFPs) will dominate the forestry industry; 2.2 = Log production from plantation forests will dominate over natural forests; 2.3 = In the context of log production from plantation forests, log production from community plantation forests will be a more developed business; 2.4 = The pulp, composite, and furniture industries will be dominant in the processing sector; 2.5 = Industries based on processing wood raw materials into pulp or paper will dominate over composite wood; 2.6 = In terms of downstream business, industries based on processing wood raw materials into pulp or paper will dominate over furniture; 2.7 = In terms of downstream business, composite wood raw material processing-based industries will dominate more than furniture; 2.8 = In terms of downstream business, composite wood raw material processing-based industries will dominate more than pulp; 2.9 = In terms of downstream business, industries based on processing wood raw materials (sawn timber and log) for furniture will dominate over pulp replace natural forests as the main provider of timber commodities. It is anticipated that the dominance of log production from plantation forests will continue to increase.

Nurrochmat et al. (2015) state that the plantation forest industry, specifically log-based industries, is anticipated to have better prospects for development compared to natural forest production. The Indonesian Central Bureau of Statistics (BPS) (2020) reports that log production from plantation forests surpasses that from natural forests, with 45.37 million cubic meters and 5.28 million cubic meters, respectively. The data indicates a consistent trend of increasing log production in plantation forests and declining production in natural forests. The Ministry of Environment and Forestry (KLHK) also observes a rising trend in log production from Indonesia's plantation forests (KLHK, 2022; Figure 4). Additionally, community plantation forests are seen as a thriving business within this industry.

Linearly, this increase in plantation forest capability will also have an impact on the dominance of processing industry types. The young foresters also anticipate that the downstream forest products industry will dominate Indonesia's forestry business in the post-COVID-19 era. They believe that the pulp industry will take the lead in the wood processing sector, followed by the composite industry, and then the furniture industry. This perspective aligns with data from the Timber Legality Information System (SILK), which indicates that paper is the primary product of the forestry industry with the highest export value and pulp has the highest export volume (KLHK, 2020).

C. Expectations concerning occupational safety and health (OSH) of those working in the forestry industry

In the context of worker competence, there is hope that in the future, attention to aspects of worker competence will get a more serious portion (Figure 5). Developing workers' competencies is important because the success of an organization or agency is highly dependent on the quality of human resources at work (Kaur & Kaur, 2022). Fieldwork in forest management activities, which is the spearhead of forest management, is executed by workers who are mostly at the level of operators and laborers. Unfortunately,

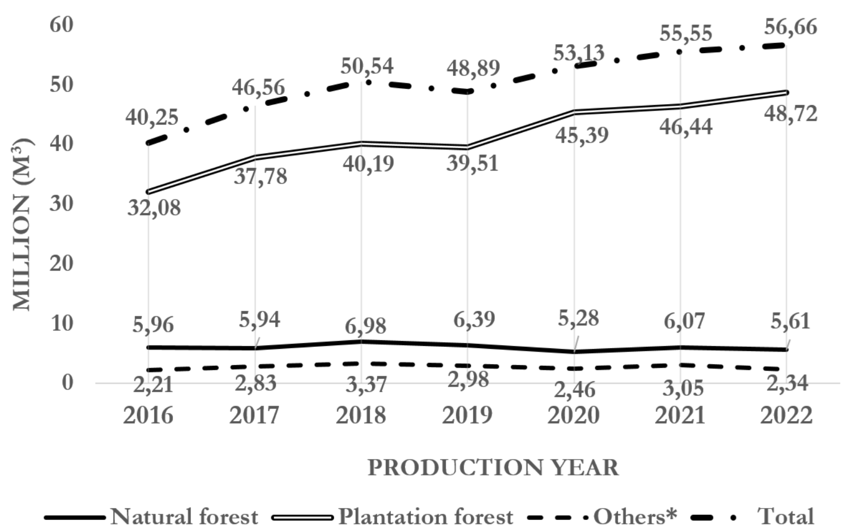

Figure 4. The rising trend in log production from plantation forests in Indonesia

Notes: *Including production from the timber processing industry, Borrow-to-Use Forestry Permits, Rights to Cultivate, private forest, State-owned Forest Enterprise (Perhutani), Social Forestry, and Forest Management Units (KLHK, 2022) the majority of Indonesian forestry workers at this level do not have the expected level of work competence and OSH protection (Yovi et al., 2016). Competence is a measure of ability that involves three interrelated elements, where the most basic element is the knowledge element. This knowledge element, in the case of Indonesian forestry workers, directly drives how the operator perceives the risk of OSH interference in his work activities so that he can then decide whether to apply precautionary behavior or not (Yovi et al., 2016). Therefore, in the case of Indonesian forestry workers, efforts to achieve the expected level of competence need to be made by ensuring workers have the right knowledge, especially on issues related to work techniques and OSH protection.

If some research recommends the implementation of bottom-up safety management (Yovi et al., 2022) young foresters still tend to think that a top-down strategy is the right strategy to be applied during the early years after COVID-19 to support effective OSH management (Figure 5). This is given the study, which noted that most front-line workers in Indonesia do not have an adequate level of knowledge, so if safety management is implemented in a bottom-up manner, this has the potential to hinder the achievement of the safety management objectives themselves (Yovi et al., 2016; Yovi et al., 2022).

Furthermore, the young forester believes that the direction of post-COVID-19 communication needs to be in a two-way direction rather than one-way. Two-way communication places the communicant more actively involved in viewing the message conveyed by the communicator so that the message will be received more clearly and steadily when compared to one-way communication (Rabiul et al., 2022). They also think that preventive efforts, mitigation and investigation efforts, commitment, and the construction of an inspection system for OSH protection need more attention after

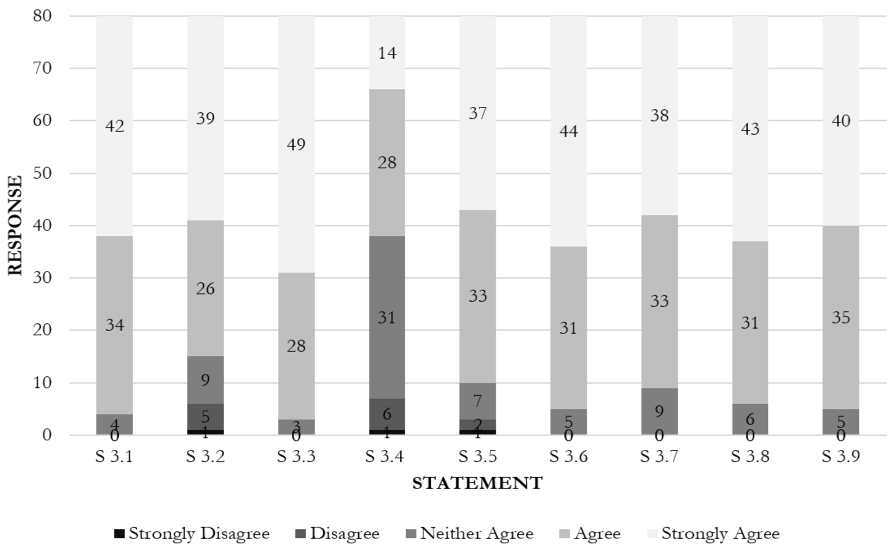

Figure 5. Young foresters' expectations of OSH protection for forestry workers after the pandemic

Notes: 3.1 = Aspects of worker competence receive more serious attention; 3.2 = Aspects of worker competence in work techniques receive more attention than aspects of OSH protection capabilities; 3.3 = OSH organization and management receive more serious attention; 3.4 = forms of OSH policy are more top-down than bottom-up; 3.5 = The two-way communication form is implemented more than the one-way communication form; 3.6 = preventive efforts in OSH protection receive more attention; 3.7 = Mitigation and investigation efforts receive more attention; 3.8 = commitment to OSH protection for workers receives more attention; 3.9 = The construction of an OSH protection inspection system receives more attention the COVID-19 pandemic. This is because Indonesia still has a low level of occupational safety when compared to developed countries that have realized how important regulations on OSH are to be implemented (Yovi & Yamada, 2019). OSH also needs more attention because it is part of the social aspects of the concept of sustainable forest management (SFM) (Yovi & Nurrochmat, 2018).

D. Strategies for maintaining or improving the efficacy of the forestry industry

In terms of strategies to maintain or improve the performance of the forestry sector at the global level, the majority of young foresters agree that Indonesia needs to synergize the upstream-downstream forestry industry so that exports of timber commodities and NTFPs can be made into finished products and add attractiveness and distinctiveness to ecotourism (Figure 6; Statement 4.1). Important efforts that can be made to improve the performance of the timber and forest products industry include upstream-downstream integration to provide optimal added value in the upstream sector (Wolf, 2011), whereas in the case of the forestry industry in Indonesia, the optimal added value potentially exists at 18.42% (Mutaqin et al., 2022). Mutaqin et al. (2022) also mentioned other strategies, such as the implementation of multiple forestry businesses (18.20%), improving forestry business governance (17.98%), improving regulations related to industries in the forestry sector (17.54%), and developing biomass-based renewable energy (14.47%).

In addition, young foresters believe that product diversification in NTFP commodities and environmental services needs to take place. Hurmekoski et al. (2018) emphasize that product diversification has a significant positive impact on the development of the forestry industry itself as well as on other related industries. Diversification in wood products is considered sufficient, but optimization needs to continue (Figure 7). The government must continue to encourage the development of the forestry industry in Indonesia by strengthening various

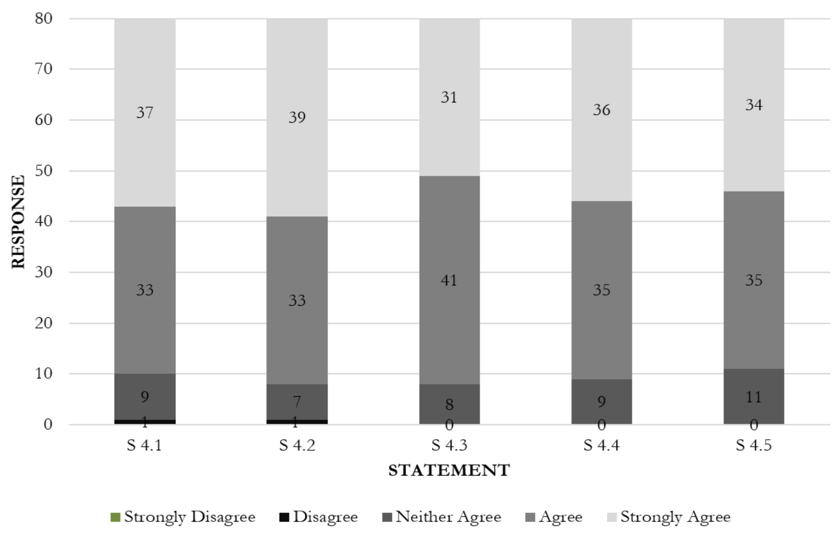

Figure 6. Strategies to maintain or improve forestry sector performance at the global level post-pandemic

Notes: 4.1 = Indonesia needs to synergize the upstream-downstream industry so that in timber and HHBK commodities, exports are made in finished goods; 4.2 = Indonesia needs to synergize the upstream-downstream industry so that the attractiveness and distinctiveness of environmental services increase; 4.3 = Indonesia needs to diversify its products into timber or NTFP commodities; 4.4 = Indonesia needs to diversify products in environmental services commodities; 4.5 = Indonesia needs to optimize the downstream industry so that there is an increase in commodity quality

Figure 7. Products assessed as requiring optimization in downstream industries

Figure 8. Nontimber forest products (NTFPs) commodity products that require diversification

aspects, including financial, technical, and policy (Nurrochmat et al., 2015). In addition, product diversification is also considered necessary in terms of NTFPs, particularly in the commodities of honey, rattan, essential oils, and rubber (Figure 8). Pasaribu et al. (2021) argue that in the case of Indonesia, NTFPs are a commodity rich in potential that has not yet been properly exploited.

In the context of environmental services, in the future, environmental services need to be directed towards ecotourism, nature tourism, carbon, and forest healing (Figure 9). In 2015, The International Ecotourism Society defined ecotourism as "responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education." Before the pandemic, global issues such as pollution, waste, climate change, global warming, and the extinction of flora and fauna triggered increased interest in the ecotourism sector. Several studies confirm that connecting to nature is a widely preferred way for people to escape the stresses

Figure 9. Environmental service commodity products seen as requiring diversification

experienced during the pandemic. The view that Indonesia's ecotourism industry will grow is very positive because, until now, forests are still not widely seen as producing various benefits that are not measurable (intangible) in the form of environmental services, environmental protection, genetic diversity, and others, so that forest utilization only focuses on tangible results (especially timber) and triggers excessive exploitation of forest natural resources. It is recognized that, in addition to the positive benefits that ecotourism can bring (Jaafar et al., 2015), it can also have a negative impact on nature and local communities. Therefore, the direction of ecotourism business development must be directed towards the concept of "sustainable tourism", which means that an appropriate balance between environmental, economic, and socio-cultural dimensions must be established to ensure long-term sustainability (UNWTO, 2023). It should be noted that ecotourism is defined as visits to natural areas that protect the environment and develop the welfare of local communities (Das, 2011). This means that the future development of ecotourism in Indonesia should be based on preserving and protecting the environment (Ciacci et al., 2021).

E. Personal insight on the state of the Indonesian forestry industry in the future

The majority of young foresters agree that Indonesia's forestry industry will continue to grow stronger and potentially provide extensive employment opportunities after the COVID-19 pandemic (Figure 10). The results of the study by Mutaqin et al. (2022) show that social forestry has a strategic position in supporting the economic recovery of communities after the COVID-19 pandemic, through the establishment and improvement of social forestry business groups (*Kelompok Usaha Perhutanan Sosial*). They are also optimistic that the forestry industry will become one of the preferred professions after the COVID-19 pandemic, so 99% of respondents expressed their desire to have a career related to the forestry sector, of which 72% stated that they would become forestry business actors and open new jobs. This desire to become a forestry business actor is a very good thing, considering that opening new jobs in the forestry sector is quite challenging (Owuor et al., 2021). These new initiatives will serve as catalysts for economic and social development in the forestry sector, facilitating job creation,

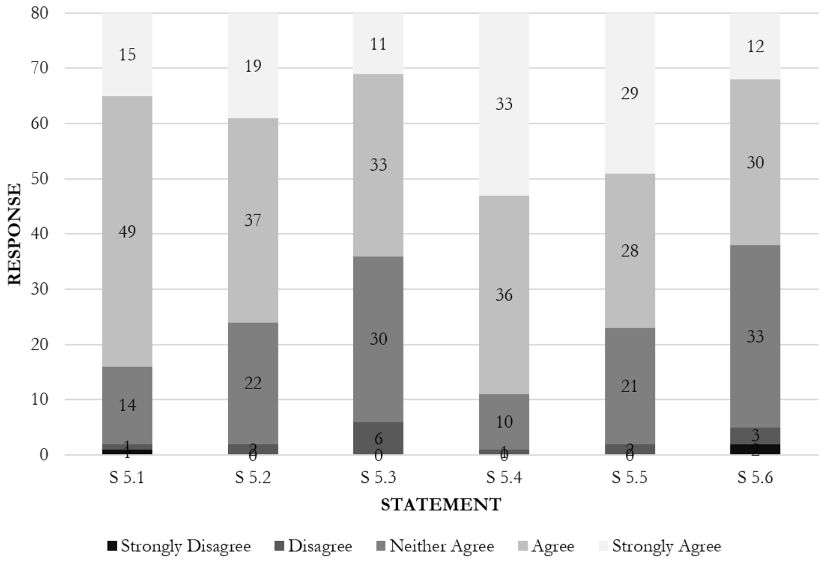

Figure 10. Personal views on the future of the forestry sector

Notes: 5.1 = Indonesia's forestry industry will grow and become stronger; 5.2 = Indonesia's forestry industry will provide ample employment opportunities; 5.3 = Indonesia's forestry industry will become one of the preferred forms of profession; 5.4 = I want to work in the forestry sector; 5.5 = I want to open new jobs in the forestry sector; 5.6 = I want to work as a worker, staff, or employee in the forestry sector

innovation, and the enhancement of procedures and processes. Martinho and Ferreira (2020) highlight the considerable hurdle faced by entrepreneurs in the forestry sector: the need to explore fresh ideas and foster innovation and entrepreneurship while operating within the framework of multifunctional forest management.

In addition to bringing new ideas and innovations, forest entrepreneurs need to use technology according to the times and collaborate with parties outside the forestry sector. One of the flourishing concepts in practice is the Internet of Things (IoT). Currently, many business managers are integrating IoT into their business activities. The integration of IoT in the management of a business has been proven to increase transparency in forest management, thereby increasing efficiency (Langley et al., 2021). IoT is a form of technology that is very appropriate to be applied in the digitalization of forests (Singh et al., 2022). With IoT, managers will be better able to detect wildfires (Zhang et al., 2019) and control smuggling by providing a more effective communication system so that appropriate actions by the authorities can be taken quickly and precisely (Sarojadevi et al., 2019).

Collaboration is understood as the relationship and sharing of information, resources, activities, and capabilities carried out by several organizations to get the desired results together, and it is impossible to get these results if done individually. Company-level cross-sector collaboration is needed to share information or make improvements that aim to direct and develop the forestry industry so that it can compete and adapt to the times. Collaborations result in enhanced learning, which is indispensable in the development of a business (Guerrero & Hansen, 2021), because learning from successful examples can help managers minimize failure or uneven results.

IV. CONCLUSION

This study emphasizes how the Indonesian young forester has an optimistic view toward the revival of the Indonesian forest industry post-COVID-19. They see the transition to developing NTFP-based industries and environmental services as potential areas of development, although they still recognize that the timber-based industry has been the backbone of Indonesia's forest industry and is likely to continue to be so with forest management moving towards plantation forestry. Young foresters also believe that substantial attention should be paid to enhancing the awareness of workers, particularly field workers, about OSH protection, which is essential to attaining sustainable forest management. The crucial efforts that need to be undertaken to improve the performance of the timber and other forest product industries are integrating upstream and downstream. Finally, the enthusiasm among young foresters to engage directly in the forestry business in Indonesia is a promising sign for the industry's revival and development. This research implies that there are significant opportunities to involve aspirations from young foresters in policy-making and the formulation of strategies for the sustainable development of the forestry sector. The findings of this study also suggest that young foresters, who still consider the forestry industry to be a promising sector to work in, need to be provided with enhanced education and training, as well as incentives for their direct involvement in supporting the forestry industry.

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POLARIZATION OF LOCAL COMMUNITY ORIENTATION TO THE DEVELOPMENT OF ECO-RURAL TOURISM IN KERINCI REGION, JAMBI PROVINCE, INDONESIA

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POLARIZATION OF LOCAL COMMUNITY ORIENTATION TO THE DEVELOPMENT OF ECO-RURAL TOURISM IN KERINCI REGION, JAMBI PROVINCE, INDONESIA. Rural areas are increasingly the focus of exploration by various stakeholders. However, local communities, as landowners in these regions, often do not reap the full benefits. This issue stems from their limited involvement in regional development and a lack of awareness about ongoing projects. Local communities play a crucial role in the success of rural development, and understanding their attitudes is vital. This study aimed to explore local community attitudes toward eco-rural tourism development in Kerinci Regency, Jambi Province. A closed-ended questionnaire, designed with a "One Score One Indicator" system, assessed various factors including socio-cultural aspects, conservation, ethnic politics, economics, regional development, tourism, and landscape ecology across six villages. The analysis of local community orientation was conducted using quantitative descriptive methods and One-Way ANOVA statistical tests. Results indicated a positive polarization in community attitudes across all villages, showing strong support for eco-rural tourism. By focusing on the identified indicators, local communities are motivated to collaborate and enhance their rural areas through eco-tourism initiatives. The findings suggest that these communities possess significant potential to develop their regions in line with eco-rural tourism principles. Additionally, the insights gained can inform the creation of eco-rural tourism programs that emphasize community involvement and leverage local strengths. This approach aims to ensure that rural communities benefit from the exploration and development occurring in their areas.

Keywords: Rural, eco-rural tourism, orientation, local community, polarization

POLARISASI ORIENTASI MASYARAKAT LOKAL TERHADAP PEMBANGUNAN ECO-RURAL TOURISM DI KABUPATEN KERINCI PROVINSI JAMBI. Kawasan pedesaan saat ini terus menjadi fokus eksplorasi oleh berbagai pemangku kepentingan. Namun, masyarakat lokal, sebagai pemilik lahan di daerah ini, sering kali tidak memperoleh manfaat sepenuhnya. Masalah ini disebabkan oleh keterlibatan mereka yang terbatas dalam proses pembangunan kawasan dan kurangnya kesadaran tentang aktivitas pembangunan yang sedang berlangsung. Masyarakat lokal memainkan peran penting dalam keberhasilan pembangunan pedesaan, dan memahami sikap serta peran mereka sangat penting. Penelitian ini bertujuan untuk mengeksplorasi sikap masyarakat lokal terhadap pengembangan eco-rural tourism di Kabupaten Kerinci, Provinsi Jambi. Kuesioner tertutup, yang dirancang dengan sistem "One Score One Indicator", menilai berbagai faktor termasuk aspek sosial budaya, konservasi, politik etnis, ekonomi, pembangunan daerah, pariwisata, dan ekologi lanskap di enam desa. Analisis orientasi masyarakat lokal dilakukan dengan menggunakan metode deskriptif kuantitatif dan uji statistik One-Way ANOVA. Hasil penelitian menunjukkan polarisasi positif dalam sikap masyarakat di semua desa, yang menunjukkan dukungan

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yang kuat terhadap eco-rural tourism. Dengan berfokus pada indikator yang diidentifikasi, masyarakat lokal termotivasi untuk berkolaborasi dan meningkatkan daerah pedesaan mereka melalui inisiatif ekowisata. Temuan ini menunjukkan bahwa masyarakat ini memiliki potensi yang signifikan untuk mengembangkan wilayah mereka sesuai dengan prinsip-prinsip eco-rural tourism. Selain itu, hasil yang diperoleh dapat menjadi dasar terciptanya program eco-rural tourism yang menekankan keterlibatan masyarakat dan memanfaatkan kekuatan lokal. Pendekatan ini bertujuan untuk memastikan bahwa masyarakat pedesaan mendapatkan manfaat dari eksplorasi dan pembangunan yang terjadi di wilayah mereka..

Kata kunci: Rural, eco-rural tourism, polarisasi, masyarakat lokal

I. INTRODUCTION

Rural as the last repositories area is still the mainstay of exploration programs by various stakeholders. The last repository area is a utilization area whose existence should also be conserved according to its potential (Feisali & Niknami, 2021; Jaafar et al., 2014). Currently, many parties want to develop rural areas for various interests due to their potential, such as entrepreneurs who develop rural areas into commercial areas to acquire large profits, even though often create disparities for the local community (Aziz et al., 2018; Long & Nguyen, 2018; Ristić et al., 2019). Some academics use rural areas as their research object but do not contribute much to the local community, NGOs with the issue of environmental protection affecting many restrictions for local communities because they are often considered exploitation, even though they need a livelihood. As well as the government with its various development planning programs which are often not well-targeted (Furmankiewicz et al., 2021; Keyim, 2018).

Many parties engage in rural development, but they do not involve the local community (Nørgaard & Thuesen, 2021). This has resulted in various forms of regional development being not optimal and unable to prosper the local community in the area, for example in Jammu and Kashmir – India (Ramjit, 2015), Mourne – Northern Ireland (Mcareavey & Mcdonagh, 2011), and Hesse – Germany (Kallert et al., 2021). Local communities usually lack of power and knowledge to develop their area, so it is necessary to increase capacity and proper understanding regarding the direction of rural area development in accordance with their potential, so they will be able to continue to develop, be independent, and sustainable (Masud et al., 2017; Nørgaard & Thuesen, 2021).

Numerous rural development concepts are emerging, for example rural development based on agricultural-, local community-, nature-, local culture-, integrated rural development, and sustainable rural development (Amir et al., 2015; Rasoolimanesh et al., 2017). All concepts are positively aimed at realizing sustainable rural areas. Although for most cases of rural development, such as tourism villages, the desired sustainability purpose was not realized (Randelli & Martellozzo, 2019). This condition is one reason that led to the emergence of eco rural tourism concept that attempts to solve things that have not yet been seized from previous development concepts (Amir et al., 2015; Ristić et al., 2019).

Eco-rural and eco-rural tourism is a new concept offered to build sustainable rural areas with a demand approach (Park & Yoon, 2011). To create various added values, the village itself with its whole potential is the development subject on eco-rural concept. Eco-rural tourism development is aligned with rural area function (Derenne, 2008). Rural area has five important functions namely production, housing, recreational and tourism, environmental, and legacy functions.

Eco-rural tourism development requires the proper involvement of all stakeholders, particularly the local communities' involvement in the decision-making process of the tourism development process (Theobald, 2005). Participation in the local community is crucial for the following two reasons: (a) local communities will be the ones most impacted by tourist development; (b) local communities are thought to be crucial components that support the growth of tourism at each destination (Jaafar et al., 2015). Local communities' quality of life is enhanced and their cultural heritage is made sustainable via development and involvement in tourism and cultural heritage management (Amir et al., 2015; Jaafar et al., 2015; Sirisrisak, 2009).

The stakeholders' orientation involved is strongly influencing the development success or failure and one of them is the local community (Amir et al., 2015; Dorobantu & Nistoreanu, 2012). The goals of eco-rural tourism development consist of 3 aspects, namely: (a) to provide an awareness that the rural development subject is not just a tourism attraction, but the rural area itself, (b) to implement rural development orientation from the concept of bottom-up (local communities demand based on the unique potential), and (c) realizing sustainable rural development with tourism development based on the unique potential to obtain socio-cultural, ecological, and economical added value (Andreopoulou et al., 2014; Marzo-Navarro et al., 2015; Mcareavey & Mcdonagh, 2011).

The statement of "local communities must be the subject of the development of an area" provides a strong reason that knowing the polarization of the orientation of local communities is appropriate to study hence direction of regional development is in accordance with the concepts owned by local communities. In addition, local communities will be very enthusiastic in carrying out the development process if things are carried out in accordance with their expectations and they will have a higher sense of responsibility in protecting the area (Longart et al., 2017; Manaf et al., 2018).

Efforts to identify characteristics of local community orientation towards ecotourism development are one strategy to increase local community participation development. The participation of the community is a basic manifestation of the spirit of self-reliance, where all actions stem from the demands or interests of the community itself (Sewell & Coppock, 1977). Since local communities play a significant role in the development of tourism, it is vital to take into account their attitudes and perspectives (Manaf et al., 2018; Prabhakaran et al., 2014; Tosun, 2000).

Two factors might be used to highlight how the idea of community participation has consistently evolved over the past few decades and become essential to the tourism development process: participation in decision-making and benefit-sharing (Tosun, 2000; Wartika & Fitriyah, 2017). One factor influencing how tourism develops is community engagement. This factor also shows how supportive the community is of tourism development, which is applicable to eco-rural tourism development. (Lee et al., 2018; Pfueller et al., 2011). The perception of the local community for the tourism impact highly depends on their involvement in the tourism activity (Jaafar et al., 2015; Prabhakaran et al., 2014). Through information sharing and emotional interactions with other communities and tourism stakeholders, local communities can enhance their sense of community and develop their self-development abilities. They can also obtain additional resources and economic benefits to improve their welfare through tourism-related activities (Chin & Lo, 2017; Ioannides, 2017; Nunkoo & Ramkissoon, 2012). Local communities with higher levels of tourism engagement are more likely to flourish through financial management and the maintenance of a positive view on life, which will lead to increased psychological well-being and financial security (Baniya et al., 2018; Furmankiewicz et al., 2021). The perception of the benefits of tourism, such as monetary gains, abilities for self-improvement, and emotional bonds, further shapes the views of the local community toward tourism. Perceptions in the local community of the social, cultural, and economic benefits of tourism (Lee et al., 2018) as well as the enhanced sense of individuality, self-worth, and self-efficacy that result from it (Rosalina et al., 2021; Shen et al., 2019; Yu et al., 2020), play significant roles in affecting their attitudes toward tourism.

Several efforts can be made to increase local communities' involvement in rural tourism activities. One of them is the participation of nearby towns in tourism-related businesses, such as lodging, food service, and souvenir sales, which generate employment and boost local economies (Šegota et al., 2017; Shen et al., 2019), thereby improving communities' overall living conditions. According to Nicholas et al. (2009), involving locals in tourism management can improve environmental awareness and encourage local ecological protection. Participating in the community also means working together to achieve shared objectives, which is crucial for the local community and involves learning how to form strong relationships and constructive interactions. (Hwang et al., 2012; Keyim, 2018; Malihah & Setiyorini, 2019). Based on evidence those involved in tourism management aspects, such as programs for historical and cultural conservation, are more likely proud of their indigenous culture and traditions (Lee et al., 2018; Pfueller et al., 2011). The involvement can strengthen the community identity sense and belonging. Effective mediation of the competing interests of different interest groups can be achieved by community inclusion in tourism development and the general promotion of positive community relations (Liu et al., 2020; Sirisrisak, 2009; Wang et al., 2021).

According to Tosun (2000), community involvement is an important way to support communities in determining their needs, assessing developer or governmental decisions, and gaining decision-making authority over development. As a result, locals will act as true hosts and provide local solutions to issues. Greater involvement in tourist development by local communities typically views tourism as a key driver of personal fulfillment (Kim, 2018; Nunkoo & Ramkissoon, 2012; Volo, 2017; Wang et al., 2021). Participation in the community also gives residents the chance to encounter a variety of personalities from beyond their area, experience diverse cultures, and broaden their horizons. (Longart et al., 2017; Masud et al., 2017; Prabhakaran et al., 2014; Priatmoko et al., 2021). Stated differently, encouraging the local people to participate in tourist development will assist their ability to make educated judgments, enhance their cultural literacy, and live according to their values.

Several studies related to local communities in tourism and rural area development generally focus on identifying the participation and effect of tourism or development activities (post-development), for example in Rural Semnan Province – Iran (Egbali et al., 2011), Jinshitan – China (Yang et al., 2021), and Phoenix Ancient Town – China (Su et al., 2018). Meanwhile, this study focuses on analyzing local community orientation during earlier stages of eco-rural tourism development (pre-development). Therefore, research on the polarization of local community orientation towards eco-rural tourism development becomes relevant to be applied. Using case studies of six villages in the Kerinci Regency of the Jambi Province, this study seeks to investigate the polarization of local community orientation toward eco-rural tourism development among rural communities. How will be the pattern of local community orientation towards the eco-rural tourism concept? What is the polarization direction of local communities in the development of eco-rural tourism?.

II. MATERIAL AND METHOD

A. Research Location and Time of Data Collection

The research location was in Kerinci Regency, Jambi Province from December 2020 to October 2021. Geographically, Kerinci Regency is situated between 1o40'S to 2o26'S and 101o08'E to 101o50'E, with north and west bordering West Sumatra, Bengkulu Province in the south and east bordering Merangin and Bungo Regency, Province Jambi. According to the results of the Bappeda-Litbang analysis (2020), Kerinci Regency covers about 6.64% (3,449.90 km2) of Jambi Province. Approximately 59.34% (2,047.03 km2) of Kerinci Regency is in Taman Nasional Kerinci Seblat-TNKS (Kerinci Seblat National Park) and 40.66% (1,401.87 km2) is residential and farming area. The villages in this study are topographically varied, with elevations between 500 m and 3,805 m above sea level and temperatures between 18.6°C and 28.9°C. The data collection location was 6 villages in 6 districts spread across Kerinci Regency, which include/close to the TNKS area, consisting of Danau Tinggi (Gunung Kerinci District), Mekarjaya (Kayu Aro District), Sawahan Koto Majidin (Air Hangat District), Koto Petai (Tanah Cogok District), Lempur Mudik (Gunung Raya District), and Pulau Sangkar (Bukit Kerman District). These six villages were selected based on the representation of village distribution in the Kerinci District spatially and by natural and cultural characteristics. In addition, these villages are development priority villages based on the Decree of the Minister of PDTT RI No. 126 of 2017 regarding priority villages for village development targets. The results of this study are expected to be applied by the local community to develop eco-rural tourism optimally in their respective villages so that the desired sustainable rural area can be realized.

B. Methods

The samples of respondents in this study were selected using the purposive sampling method based on local community groups who play a direct role and have impacts on the eco-rural tourism development in their villages, the respondents consist of: (1) the general public, (2) traditional leaders, (3) Religious leaders/ scholars from 6 villages. Thirty respondents were selected from each village, bringing the respondents total number to 180 people (Table 1).

C. Analysis

There are two analyses in this study, namely analysis of the orientation pattern of the local community on the eco-rural tourism concept and an analysis polarization of orientation of the local community towards eco-rural tourism developments:

1. **Analysis of pattern of local community orientation of eco-rural tourism**

   The analysis was conducted to observe local communities' eco-rural tourism perception developed in the rural areas. Seven components, 49 criteria, and 343 indicators that were generated through the processing of diverse literature and field research on eco-rural tourism development were used to

Table 1. Number of respondents

Local community	Assessed village						Total
	Danau Tinggi	Mekar Jaya	Sawahan Koto Majidin	Koto Petai	Lempur Mudik	Pulau Sangkar	
General public	20	20	20	20	20	20	120
Traditional leaders	5	5	5	5	5	5	30
Religious leaders	5	5	5	5	5	5	30
Total	30	30	30	30	30	30	**180**

evaluate the perception of local communities (Table 2). For closed questionnaire data from each evaluated indicator criteria aspect, the One Score One Indicator Scoring System has been used. One Score One Indicator Scoring System analysis is a methodology of analysis that entails developing a number of questionnaires to gather information and assess different factors that researchers have identified (Avenzora, 2008). The scores on each aspect of eco-rural tourism were obtained with a range from 1–7 (development from 1-5 Likert scales).

1 = strongly irrelevant,
2 = irrelevant,
3 = somewhat irrelevant,
4 = neutral,
5 = somewhat relevant
6 = relevant,
7 = strongly relevant.

The relevance of eco-rural tourism concept can be represented by the score obtained. The higher the score, the more relevant the idea of rural eco-tourism for implementation and development in rural area, and vice versa.

2. Local community analysis orientation on the eco-rural tourism development

Using quantitative descriptive approaches, an analysis of local community orientation perceptions of eco-rural tourism development was carried out. Polarization indications of local community orientation are assessed using comparative methods One Way ANOVA statistical test. Local community orientation polarization can be shown in the distinctive differences in a score of each village respondent's perception for aspects (criterias and indicators) of eco-rural tourism development. The P-value, or significant value, indicates average the score difference test. Local community orientation polarization is categorized into two categories, that is direct and scale polarization (Haribawa et al., 2020; Untari et al., 2019). The polarization orientation

Table 2. Aspects of assessment for eco-rural tourism concepts

No	Aspects	Assesment criteria
1.	Socio cultural	Life values and kinship, art, knowledge, communication and language systems, beliefs, and customary rituals.
2.	Conservation and environmental	The society relevances to the utilization, protection, and management of cultural, human, and natural resources.
3.	Ethnic Politic	Customary laws and sanctions, customary government systems and decision-making, traditional leaders and their elections, and community participation in traditional government.
4.	Economics	Natural resources and technology in the business/industry's raw material processing, production elements and marketing, incentives, community technical capabilities, and financial management knowledge.
5.	Regional development	Regional growth centers, regional development programs and factors, sustainable development, community participation, rural area infrastructure facilities, and rural development cooperation.
6.	Tourism	The accessibility of natural and cultural resources as tourist attractions, community involvement in the development of sustainable tourism, the availability of facilities and management activities at tourist objects/areas, and the added value of tourism activities.
7.	Ecological landscape	In addition to horizontal structures and natural and artificial landscape elements, structural dynamics and changes (horizontal and vertical) and landscape functions are also included.

of the local community has a positive value if the average value is more than or equal to 4 and otherwise a negative value if the average value is less than 4. The F-value and its significance value show the polarization scale's magnitude. The polarization scale is strong if the p-value is less than or equal to α or if the F-value is greater than or equal to the F-table. Conversely, if the p-value exceeds α or the F-value is smaller than the F-table, the polarization scale is low 3.

III. RESULT AND DISCUSSION

A. Validity and Reliability Test of Research Aspects

The validity and reliability tests results on the aspect of the local community orientation assessment were declared valid with r-value > r-table, and reliable with Cronbach Alpha > 0.65 (Table 3). The assessment aspect of the local community orientation can be analyzed further.

Table 3. Reliability and validity test of eco rural tourism aspects

Aspects	Product moment correlation (r)	Cronbach's Alpha
Socio-cultural	0.860**	0.956
Conservation and environmental	0.916**	0.951
Ethnic Politics	0.882**	0.954
Economics	0.923**	0.950
Regional development	0.940**	0.948
Tourism	0.875**	0.956
Ecological landscape	0.911**	0.953

Notes: **) Sig. (2-tailed) = 0.000 and p value < 0.05, r-value > r-table (0.160) = Valid Cronbach's Alpha > 0.65 = Reliable

B. Local Community Orientation Pattern on Eco-rural Tourism Concept

The eco-rural tourism concept of local community orientation pattern was observed from local community perception assessment towards indicator criteria relevance in developing eco-rural tourism for their respective rural area. Based on the demands of rural areas, seven aspects are evaluated (Table 2) and decided (Altinay & Paraskevas, 2007; Pfueller et al., 2011). Local communities evaluate seven criteria in each area based on several studies and literature advancements.

1. Aspects of Socio-cultural

The various systems that were established and used in rural communities are connected to the socio-cultural aspects. There are seven criteria for assessment in this aspect: 1) system of community communication, 2) system of language, 3) system of art, 4) system of social life value, 5) system of kinship, 6) system of knowledge, and 7) system of traditional ritual and belief. Figure 1 displays the value of the local community's perception of criteria on socio-cultural aspects, with categories somewhat relevant to relevant (scores above 4). With an average score of 6.48, the social life value criteria system has the highest average. The criteria illustrate that on average local community agrees to maintain values, such as 1) mutual consensus in decision-making, 2) social life mutual cooperation, 3) social life sense of kinship, 4) social life tolerance, 5) social life manners, 6) local wisdom, and 7) applicable norms. This also can be interpreted as relevant criteria for eco-rural tourism development realization. Cultural values with their uniqueness and distinctiveness are the potential for local development (Takaendengan et al., 2022). The lowest average score of 5.94 is observed in traditional ritual and belief system criteria. This criteria describes the average local community agrees in conducting as follows: 1) appreciating ritual systems and beliefs, 2) gathering sources of ritual systems and beliefs, 3) utilizing ritual systems and beliefs in everyday life, 4) developing ritual systems and beliefs, 5) preserving all assets of ritual systems and beliefs, 6) disseminating ritual systems and beliefs to communities, and 7) creating and/or optimizing the socio-cultural benefits of ritual systems and beliefs in everyday life. Based on the evaluated score, the criteria can be seen as relatively significant to the development of eco-rural tourism. Every village's local community has a unique perspective on each of the sociocultural elements that are being evaluated. However, the difference is not dominant, so the perception direction remains positive and relevant to be criteria in eco-rural tourism development.

2. Aspects of Conservation and Enviromental

Aspects of conservation and environmental include also conservation principles: protection, utilization, and management. There are seven criteria assessed in the aspect: 1) natural resources protection, 2) cultural resources protection, 3) natural resources utilization, 4) cultural resources utilization, 5) natural resources management, 6) cultural resources management, and 7) human resources management. The local community's perspective on environmental elements and conservation is shown in Figure 2, along with pertinent categories (score above 5). The category for protecting natural resources (A) receives the highest average score, 6.47. This criteria describes that on average local community agrees that they need to take actions including: 1) protecting conservation areas, 2) protecting clean water sources, 3) protecting the diversity of flora species, 4) protecting the diversity

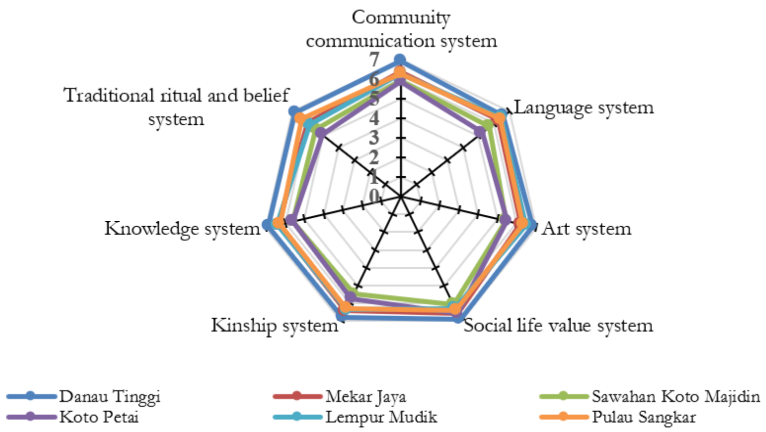

Figure 1. Local community perception of socio-cultural aspect

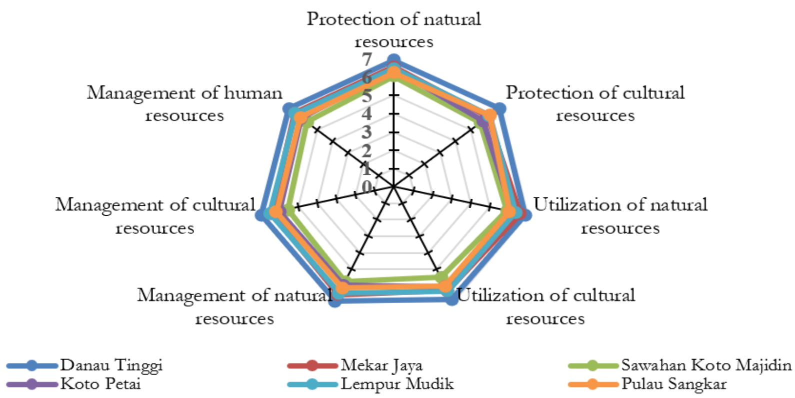

Figure 2. Local community perception of conservation and environmental aspect

of fauna species, 5) protecting the diversity of geophysical potential, 6) protecting land agriculture/fields/farming, and 7) protecting natural resources that are milestones in the enforcement of customary trust order. Based on the assessment, the criteria are relevant to one of the requirements in eco-rural tourism development. Like other criteria, local community perceptions show an average score of > 6 (6.15 – 6.30). In conclusion, the growth of eco-rural tourism is impacted by all of the conservation and environmental criteria.

3. Aspects of Ethnic Politics

The impact of rural communities' customs on their way of life is one aspect of ethnic politics. This aspect was cascaded to seven criteria: 1) traditional leader, 2) election of a traditional leader, 3) customary law, 4) customary sanction, 5) customary government system, 6) customary decision making, and 7) roles of the community towards customary government. The value of the local community's assessment of the relevant categories (scores over 5) for ethnic politics criteria is shown in Figure 3. With an average score of 6.38, the customary law criteria obtain the highest rating. This criterion describes the average local community agrees that local communities need to understand customary laws such as 1) marriage law, 2) property division law, 3) dispute resolution, 4) violations of ethics/norms, 5) social order law, 6) economic order law, and 7) development order law. Ethnic political conditions in each village can be different as well as their implementation due to the pattern held for generations, but all agree that ethnic politics was one of the aspects of an important role for rural area development. It can be concluded that the criteria evaluated by the local community on ethnic politics elements are relevant to the development of eco-rural tourism, while other criteria also show an average score of > 6 (6.20 – 6.35).

4. Aspects of Economic

Aspects of economic assessment will display the extent to which people can understand the production activities in the community to improve the community's economy. In this aspect there are seven criteria for assessment: 1) natural resources as raw material for business/industry, 2) traditional equipment/technology for processing raw material, 3) aspect of production, 4) network marketing, 5) knowledge of financial management, 6) community incentive, and

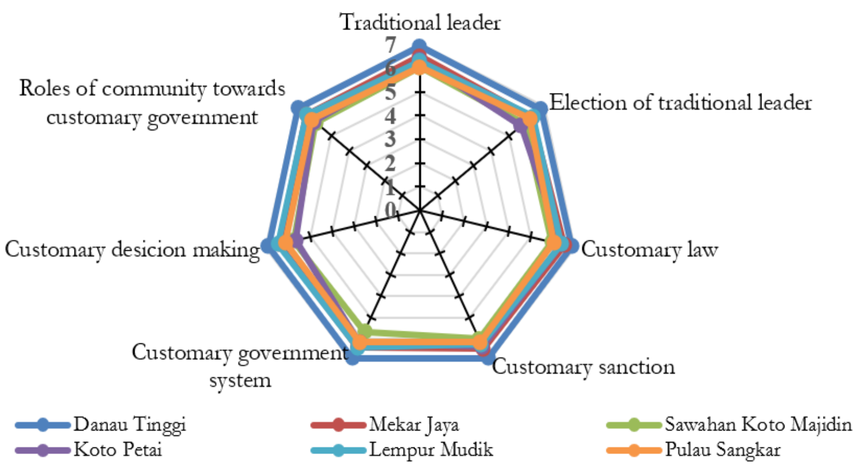

Figure 3. Local community perception of ethnic politics aspect

7) community technical skill. Figure 4 shows the relevance of the local community's perception of the economic aspect criteria, with a score over 4 indicating a somewhat important category. With an average score of 6.26, the community technical skills criteria have the highest average. According to the criteria, the local community acknowledges that in order to achieve eco-rural tourist development, the following actions are necessary: 1) know types of technical skills, 2) determine technical skills requirement, 3) have a training program to improve technical skills, 4) have partners for human resource distribution for each skill, 5) set standards of technical skills, 6) develop businesses according to technical skills, and 7) develop the integration of technical skills with other skills. The lowest average score of 5.92 is observed in the marketing network criteria. This criterion describes local community knows about niche markets for products owned by rural communities to develop eco-rural tourism. Figure 4 also shows the differences in people's perceptions between villages do not affect the value of relevant aspects which remain positive.

5. Aspects of Regional Development

A crucial factor in determining the course of rural development is the observation of regional development characteristics. The seven factors that contribute to sustainable rural development are 1) rural community engagement in development, 2) regional development program; 3) center for rural area growth, 4) sustainable rural development, 5) rural area infrastructure, and 6) rural area development cooperation. Figure 5 shows that the local community perception value of criteria on regional development aspects is positive with somewhat relevant categories (scores above 4). With an average score of 6.34, participation in rural community criteria has the highest average. These requirements show that the local community consents to carry out the subsequent actions for the development of rural areas: 1) realizing the importance of participation, 2) creating participation patterns and system, 3) determining resource and needs allocation for participation, 4) increasing the knowledge capacity for participation, 5) developing strategies to strengthen participation, 6) developing strategies for participation program implementation, and 7) developing participation integration among stakeholders in rural development. The assessment can also consider the criteria to be relevant to eco-rural tourism development. Meanwhile, the lowest average score of 5.93, which means somewhat relevant in developing

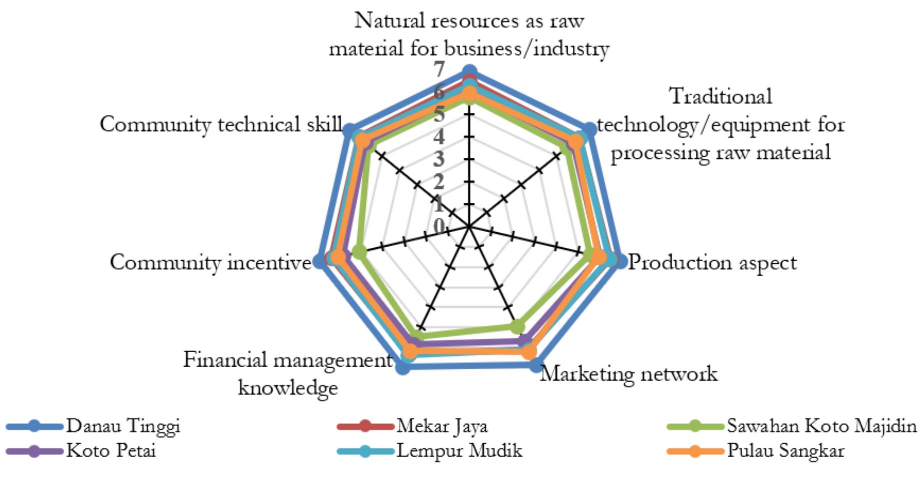

Figure 4. Local community perception of economic aspect

eco-rural tourism, is observed in the criteria of regional development factor. The indicators in this criteria are as follows: rural communities need to elaborate: 1) regional development grand design, 2) development harmonization patterns among clusters within regional areas, 3) regional development pattern implementation, 4) participatory funding pattern, 5) providing facilities and information pattern, 6) providing qualified human resources pattern, and 7) using a community innovation development pattern to boost regional development's competitiveness.'

6. Aspects of Tourism

Since tourism adds value to the potential of rural communities, it is one of the key components in the development of eco-rural tourism. The following seven criteria can be used to characterize the assessment for this aspect: 1) the availability of natural potential as a tourist attraction; 2) the availability of cultural potential as a tourist attraction; 3) the availability of facilities at the tourism object or area; 4) tourism activity; 5) management activities related to the tourism object or area; 6) value addition to the tourism activity; and 7) development of sustainable rural

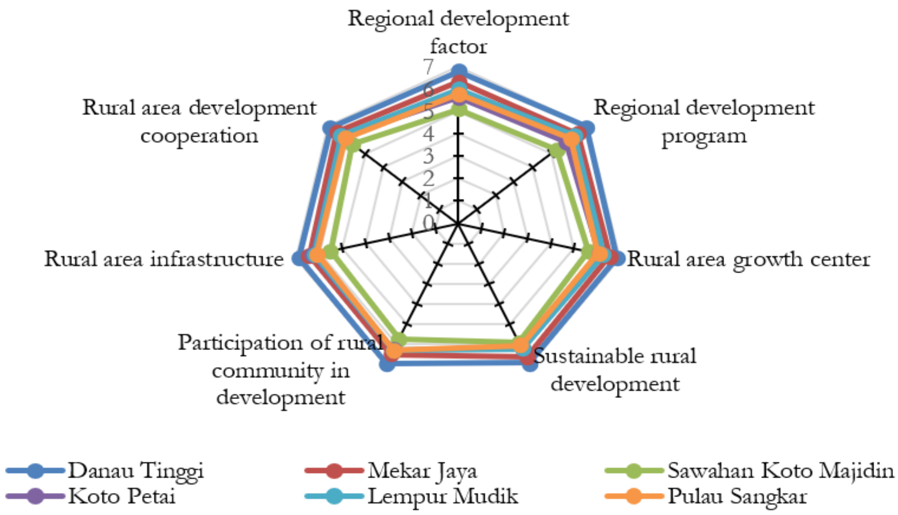

Figure 5. Local community perception of regional development aspect

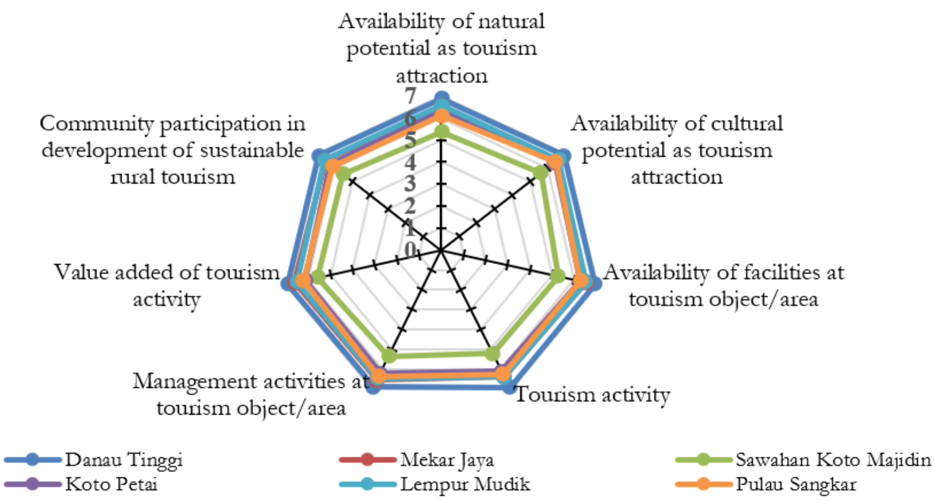

Figure 6. Local community perception of tourism aspect

tourism community participation. Figure 6 displays the perception value of the local community towards tourism aspects criteria with relevant categories (scores above 5). The criterion with the highest average score, 6.39, is the availability of cultural potential as a tourist destination. The criteria show that local communities agree that it is necessary to: 1) identify the types and diversity of cultural potentials, 2) identify the spread of cultural potential, 3) develop open access to cultural potential, 4) protect the uniqueness and authenticity of cultural potential, 5) understand the sensitivity of cultural potential, 6) develop patterns of utilization of cultural potential, and 7) understand the socio-cultural functions available for tourism attraction. The evaluation's findings show that the criteria are pertinent to the growth of eco-rural tourism. The average score for the remaining criterion is likewise shown in Figure 6 and spans from 6.20 to 6.32, indicating that all criteria related to the tourist component are pertinent to the development of eco-rural tourism.

7. Aspects of Ecological Landscapes

The structures, elements, dynamics/changes in structure, and changes in function in rural areas are covered in the aspects of ecological landscape. Seven criteria are evaluated, which include: 1) partially natural elements, 2) artificial elements, 3) horizontal structures of natural and artificial landscape composition, 4) horizontal structures of artificial landscape composition, 5) dynamics and changes in the composition of vertical landscape structure, 6) dynamics and changes in the composition of horizontal landscape structure, and 7) dynamics and changes in the function of the landscape. Figure 7 displays the perception value of the local community towards ecological landscape aspects criteria with relevant categories (scores above 5). Natural landscape elements criteria have the highest average score of 6.15. This criteria indicates that local people agree it is necessary to conduct the following item as relevant for eco-rural tourism development: 1) knowing and identifying natural landscape elements variety and characteristics, 2) knowing and identifying natural landscape elements location and distribution, 3) knowing and applying natural landscape elements patterns of utilization, 4) knowing and applying natural landscape elements patterns of maintenance, 5) knowing and understanding natural landscape elements functional patterns, 6) knowing and understanding natural landscapes aesthetic

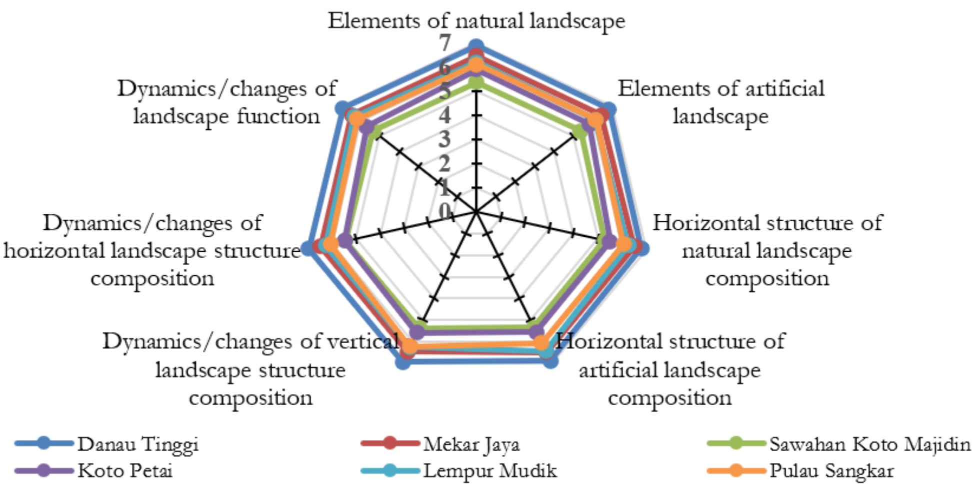

Figure 7. Local community perception of ecological landscape aspects

patterns, and 7) knowing and understanding patterns of interaction between diverse elements of the natural landscape of rural area. The stakeholder's contribution to the development of natural landscapes is vital to eco-rural tourism development including an unfamiliar element to the general public (Dewi et al., 2022). The average score for the remaining criteria in Figure 7 is similarly higher than 6, indicating that all of the criteria are pertinent to the development of eco-rural tourism. Differences in community perceptions among villages do not affect the value of relevant aspects that remain positive.

C. Local communities polarization towards eco-rural tourism development

Overarching guidance for nearby communities Polarization orientation is positive (score > 4) with respect to the eco-rural tourist development idea. The local communities concur that certain components of the eco-rural tourism concept are pertinent for the development of sustainable rural areas, as indicated by the average score of more than six on each facet. Figure 8 shows a summary of the polarization direction of all areas of the development of eco-rural tourism.

Table 4 displays the differences in scores for each respondent group based on the significant

Table 4. Difference test of local community orientation score towards eco-rural tourism development

Aspects	Test Parameters		
	Mean	F-calculated	Sig.
Socio-cultural	6.18	21.580	0.000
Conservation and environment	6.28	19.333	0.000
Ethnic politics	6.30	14.244	0.000
Economics	6.17	21.402	0.000
Regional development	6.22	20.891	0.000
Tourism	6.31	19.928	0.000
Ecological landscape	6.12	22.887	0.000

Notes: Description: If F-calculated ≥ F-table or p-value or Sig ≤ 0.05, there is a noticeable difference in the average value. F-table for $\alpha = 0.05$; df (6; 150) is 2.16

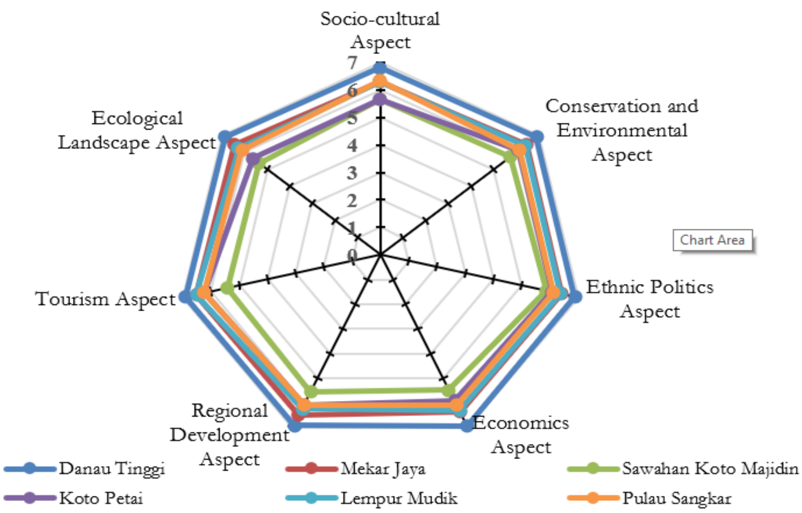

Figure 8. Eco-rural tourism development polarization

value (p-value < 0.05 or F-value ≥ F-table) for each aspect of the polarization scale. The significance value of the polarization scale in the table indicates a strong intensity. This suggests that local populations are interested in seeing eco-rural tourism grow in their regions.

With an average score of 6.31, the polarization direction of tourist features is shown in Table 4, indicating that the local people believed that tourism factors would add value to the area. The availability of natural potential, cultural potential, facilities, and tourism activities bolstered by effective management practices and local community involvement in the development of sustainable rural tourism results in added value. Natural and cultural tourism are the most popular tourist attractions in rural areas (Leduc et al., 2021). With a score of 6.30, Table 4 further demonstrates the favorable direction of polarization in the ethnic politics element. The existence of traditional leaders in communities other than recognized regional leaders, the election of traditional leaders, customary laws, and customary punishments administered in rural regions can all be seen as indicators that the dynamics of ethnic politics are inextricably linked to local community life (Kallert et al., 2021).

Local communities assessed that in the eco-rural tourism development, conservation and environmental aspects, regional development aspects, socio-cultural aspects, economic aspects, and ecological landscape aspects also need to be fulfilled (Dorobantu & Nistoreanu, 2012). Polarization is positive (average score of 6.28) on conservation and environmental aspects, meaning that the community must apply conservation principles, namely protection, utilization, and management of natural and cultural resources (Haribawa et al., 2020). The feature of regional development that is also favorable (average score of 6.22) indicates that in order to make rural regions sustainable, local communities need to be actively involved in articulating regional development factors and programs, understand the hub of rural growth, and work together with infrastructure facilities (Leduc et al., 2021; Ramjit, 2015). Positive polarization, which has an average score of 6.18 in the sociocultural domain, indicates that the sociocultural order and value system that has grown within society must be preserved since they have been deeply ingrained in the fabric of society. The idea of eco-rural tourism will ultimately be strengthened by the application and maintenance of the following socio-cultural aspects: systems of community communication, language, art, social life values, kinship, knowledge, and traditional rituals and beliefs (Ahamed, 2018).

Polarization of economic aspects also has a positive direction (average score is 6.17). Local people need to understand the natural resources they have that serve as raw materials for business/industry. Raw materials processing using traditional equipment and modern technology must be synergized. Local people should maintain traditional methods of processing patterns which is their local wisdom. In addition, the people also need to understand the production aspects, marketing network, and management financial (Drăgulănescu & Ivan, 2012; Qiu et al., 2019). When creating eco-rural tourism, the ecological landscape aspect serves as a benchmark as well. Local communities must comprehend the state of the landscape, which is made up of both natural and artificial landscape elements, horizontal and vertical structures, and structural dynamics and changes that can create a landscape typical for the area, according to the aspect positive direction (average score of 6.12). The more distinctive a rural location is, the more value can be created (Carneiro et al., 2015; Lu et al., 2020).

The result shows that most local communities in all villages want eco-rural tourism development in their respective village areas which is expected can increase socio-cultural, economic, and ecological value in the community. According to Efendi (2002:2), development must be planned and oriented towards community development, which is also relevant to Shaffer et al. (2004). Development is a gradual, sustainable process that involves intensifying, adjusting, and developing resource use to support people and communities. Collaboration and quality of cooperation among stakeholders are also essential to the effective and long-term development of eco-rural tourism (Munajat et al., 2022). The plan of action to keep the polarization trending in a favorable way is to keep educating the local population about the significance of routinely evaluating the application of eco-rural tourism criteria and indicators in their village areas.

IV. CONCLUSION

Polarization direction in eco-rural tourist growth can be ascertained using information on local community orientation. According to the perspective of the local community, the idea of eco-rural tourism in the development of rural areas was pertinent and should be implemented in each of their communities. Tourism, ethnic politics, environmental conservation, regional development, socio-cultural, economic, and ecological landscape characteristics are the factors that become the local community's strength in eco-rural development. Based on the orientation of the local community, the polarization direction of eco-rural tourist growth exhibits a strong polarization scale and a positive direction. This indicates that local communities have decided to work together to use the developed indicators to transform their rural areas into eco-rural tourism.

The idea of eco-rural tourism offers local communities a wonderful opportunity to improve their rural areas. The construction can improve the quality of life in the neighborhood and create a sustainable rural area. The best way to keep the polarization trend going in the right direction is to keep educating the locals about the significance of evaluating the application of eco-rural tourism criteria and indicators in their villages on a regular and ongoing basis. The stakeholders with policy-making roles should initiate planning for local community involvement in each step of programs, allocate a proper budget for promoting eco-rural tourism-based development, and generate a committee to evaluate program implementation in a timely manner. Local communities are not the only determinants of polarization direction in rural area development, therefore a common understanding is needed among other stakeholders related to the eco-rural tourism development to realize it according to its purpose.

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STAKEHOLDERS ANALYSIS OF MANGROVE ECOSYSTEM MANAGEMENT IN SEGARA ANAKAN LAGOON, CILACAP

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STAKEHOLDERS ANALYSIS OF MANGROVE ECOSYSTEM MANAGEMENT IN SEGARA ANAKAN LAGOON, CILACAP. The mangrove ecosystems are one type of coastal ecosystem found along coastlines and river estuaries that are influenced by tides and inundation. Segara Anakan Lagoon, Cilacap as one type of coastal ecosystem has a protection function, coastal area buffer, and cultivation area function that must be supported from the aspects of policy and institutions, communication, and coordination. This study aims to identify the role of stakeholders and the relationship between stakeholders in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap. The research method used was a survey and interview method analyzed with MACTOR software. The results showed that there were 18 stakeholders who involved in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap. The stakeholders are classified into main stakeholders, key stakeholders, and supporting stakeholders using the objective of mangrove management as key activities such as silvofishery, mangrove conservation, fishing activity, industry activity, etc. The level of convergence between stakeholders was 96.1% and the level of divergence was 3.9%. These results indicate a relatively low potential for conflict between stakeholders. The research can be used as a model relation between stakeholders to support the management activity of Segara Anakan Lagoon.

Keywords: Mangrove ecosystem, management, Segara Anakan Lagoon Cilacap, MACTOR software, stakeholders

ANALISIS PELAKU PENGELOLAAN MANGROVE DI LAGUNA SEGARA ANAKAN, CILACAP. Ekosistem mangrove merupakan salah satu tipe ekosistem pesisir yang terdapat di sepanjang garis pantai dan muara sungai yang dipengaruhi oleh pasang surut air laut dan genangan. Laguna Segara Anakan, Cilacap sebagai salah satu tipe ekosistem pesisir memiliki fungsi perlindungan, penyangga wilayah pesisir dan fungsi kawasan budidaya yang harus didukung dari aspek kebijakan dan kelembagaan, komunikasi dan koordinasi. Penelitian ini bertujuan untuk mengidentifikasi peran pemangku kepentingan dan hubungan antar pemangku kepentingan dalam pengelolaan ekosistem mangrove di Laguna Segara Anakan, Cilacap. Metode penelitian yang digunakan adalah metode survei dan wawancara yang dianalisis dengan perangkat lunak MACTOR. Hasil penelitian menunjukkan bahwa teridentifikasi 18 pemangku kepentingan yang berperan dalam pengelolaan ekosistem mangrove di Laguna Segara Anakan, Cilacap. Peran pemangku kepentingan dikelompokkan menjadi pemangku kepentingan utama, pemangku kepentingan kunci, dan pemangku kepentingan pendukung. Yang menggunakan obyek aktivitas pengelolaan mangrove sebagai aktivitas kunci seperti tambak, konservasi mangrove, penangkapan ikan, industri dan lain-lain. Tingkat konvergensi antar pelaku kepentingan sebesar 96,1% dan tingkat divergensi sebesar 3,9%. Hasil ini menunjukkan potensi konflik yang relatif rendah antar pemangku kepentingan. Riset ini dapat digunakan sebagai model hubungan antar pemangku kepentingan dalam pengelolaan Laguna Segara Anakan.

Kata kunci: Ekosistem mangrove, pengelolaan, Laguna Segara Anakan Cilacap, perangkat lunak MACTOR, pemangku kepentinganr

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I. INTRODUCTION

The mangrove ecosystems are forest areas along the coastline and are influenced by tides, water inundation, soil texture, water salinity, water pH, and oceanographic factors (Azman et al., 2021; Hilmi, Sari, Cahyo, Mahdiana, & Samudra, 2021; Rastogi, Phulwaria, & Gupta, 2021). Mangrove ecosystems are unique natural ecosystems and have high ecological and economic values (Anneboina & Kavi Kumar, 2017; Dijk, Broersma, & Mehnen, 2016; Hu et al., 2020; Soares, Assunção, Fernandes, & Marinho-Soriano, 2018). The function of mangrove ecosystems includes protecting the coast from wind, currents, and waves from the sea, as well as being a habitat (place to live), feeding ground, and spawning ground for aquatic biota (Leo, Gillies, Fitzsimons, Hale, & Beck, 2019; Marlianingrum, Kusumastanto, Adrianto, & Fahrudin, 2021; Sihombing, Gunawan, & Sawitri, 2017). Mangrove forests also can produce firewood, construction wood, charcoal, dyes, syrup, and others. Mangrove also has an important function in supporting the activity of carbon dioxide sequestration to reduce the impact of global warming (Azman et al., 2021; Ely, Tuhumena, Sopaheluwakan, & Pattinaja, 2021; Hartoko, Chayaningrum, Febrianti, Ariyanto, & Suryanti, 2015; Hilmi et al., 2017; Thoral et al., 2021).

Segara Anakan Lagoon located in Cilacap Regency is the largest mangrove ecosystem in Java with an area of 21.500 ha (before 1990). The Segara Anakan Lagoon also has the Center for Indonesia Mangrove Conservation Studies including Lempong Pucung Hamlet, Ujung Alang Village, Kampung Laut District, and Cilacap. The Regional Regulation of Cilacap Regency 17/2001 concerning Mangrove Forest Management in Segara Anakan develops strategic and protective benefits and potential values, and conservation of ± 56 species of mangroves (Hilmi, Sari, Amron, Cahyo, & Siregar, 2021; Hilmi, Sari, Cahyo, Amron, & Siregar, 2021; Koswara, Ardli, & Yani, 2017; Nugroho, Piranti, & Husein Sastranegara, 2020; Rachman, Hilmi, Anwar, & Penelitian, 2020; Sari, Adrianto, Soewardi, Atmadipoera, & Hilmi, 2016). However, the mangrove ecosystem in Segara Anakan Lagoon, Cilacap is currently degraded due to natural and human factors (Fatimah et al., 2022). Therefore, integrated efforts are needed to reduce ecosystem degradation. Reducing the degradation required efforts to identify and synergize the roles of stakeholders in sustainable ecosystem management and conservation efforts.

The management and conservation activity require the policy and institutional aspects to reduce the degradation trend which is caused by natural phenomena such as tidal flooding, intrusion, abrasion, water inundation, human intervention, and the limited role of the community (Gijón Mancheño et al., 2021; Hariyadi, 2018; Khan, Abdullah, Salam, Mandal, & Hossain, 2021). In addition, the government also develops policies and takes on roles and responsibilities as the mangrove forest management authority. However, these activities still have constraints and management issues, namely: overlapping authority, poor communication, lack of coordination among related stakeholders, and lack of understanding of conservation and sustainable management, and knowledge of the impacts of ecosystem damage (Fatimah, Sudharto, & Kismartini, 2022; Pace, Saritas, & Deidun, 2023; Sari, 2016; Tandio, Kusmana, Fauzi, & Hilmi, 2023)

Stakeholders in mangrove forest management are classified into government agencies, community, academic people (teachers, lecturers, and mangrove experts), mass media, and private sector (business) (Fauzi, 2019; Kalsum, Purwanto, WF, & Sumardi, 2022; Tandio et al., 2023; Triyanti & Susilowati, 2019; Wardono, Muhartono, Hikmayani, Apriliani, & Hikmah, 2019). Stakeholder analysis requires a methodology to gain an understanding of a system, assess the impact of change on a system, and identify and assess the interests of all stakeholders. Therefore, stakeholders as groups and individuals must have a certain role in achieving the conservation and management objectives of the mangrove ecosystem. The first is the government which must have good influence to develop good policies and outcomes to support mangrove conservation and management. The other stakeholders are the community, academia, private sector, and mass media which also have an important role in achieving the success of a program (Ahmad, Abdullah, & Jaafar, 2016; Ely et al., 2021; Fauzi, 2019; Glass, Kruse, & Miller, 2015; Muawanah, Kurniasari, Soejarwo, & Yuliaty, 2020; Tandio et al., 2023) Analyzing the role of the stakeholders can be done by developing stakeholders role model to support the objective of mangrove conservation and management. These activities can use MACTOR software. MACTOR as a software tool is used to measure the balance of power between stakeholders and study the convergence and divergence of stakeholders in addressing the interrelated interests and goals. MACTOR can assist in decision-making from the various interests of stakeholders to implement policies and reduce conflicts (Thompson, 2018; Triyanti & Susilowati, 2019; Wardono et al., 2019). The research aims to identify and develop the stakeholder role in managing and conserving mangrove ecosystems based on the relationship among stakeholders in Segara Anakan Lagoon, Cilacap using MACTOR software.

II. MATERIALS AND METHODS

A. Research Area

The research was conducted in February-March 2023 in Villages in Segara Anakan Lagoon (SAL), Cilacap, especially in Kotawaru, Kampung Laut, and Tritih, Central Cilacap District, Cilacap Regency. The subjects of this research were stakeholders around the Segara Anakan mangrove ecosystem. The ecosystem mangrove in Segara Anakan has specific characteristics because it is like the semi-closed lagoon and has two seawater gates that are Pelawangan Barat and Pelawangan Timur (Hilmi, Sari, Cahyo, Amron, et al., 2021; Hilmi, Sari, Cahyo, Mahdiana, et al., 2021).

B. Sampling Techniques

This research used two-stage cluster sampling technique (using village as the first parameter and stakeholders as the second parameter) to collect a sample of stakeholders from villages in East Segara Anakan Lagoon, Cilacap (Kutawaru, Tritih and Kampung Laut). The determination of the number of respondents was based on Slovin's Formula for Sampling Technique (Slovin, 1960) as follows (Saptutyningsih, Diswandi, & Jaung, 2020; Syafiq, Sirojuzilam, Badaruddin, & Purwoko, 2022)).

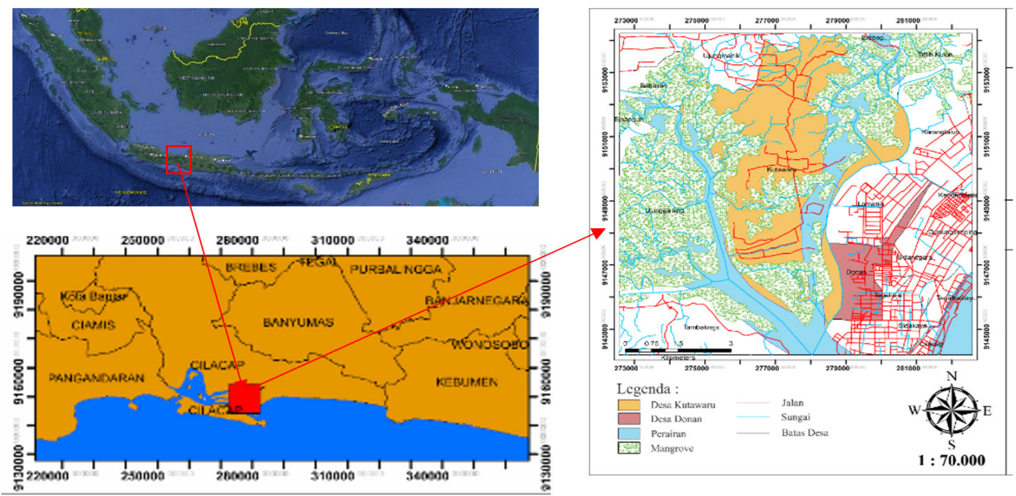

Figure 1. Map of Research Location

$$n = \frac{N}{1 + Ne^2} \quad \text{.....................................(1)}$$

Notes:
n: Number of samples
N: Total population
e: Fault tolerance limit (in this study was 25%)

Focus Group Discussion was developed following the Slovin index. Based on the Slovin Index the total number of respondents in this study was> 30 respondents. Respondents in this study consisted of the government (Central Java Province Environment and Forestry Office, Cilacap Regency Environment Office, Cilacap Regency Maritime Affairs and Fisheries Office, Donan Village Government of Cilacap Regency, Kutawaru Village Government of Cilacap Regency), academic persons (Jenderal Soedirman University), private sector/ industry (PT. Pertamina (Persero) RU IV Cilacap and PT. Solusi Bangun Indonesia Tbk. Cilacap), ecotourism managers, community (community leaders, fishermen, mangrove craft processors and craftsmen, farmers, silvofishery communities, boat transportation services, the general public, collectors, NGOs, and direct mangrove user communities).

C. Research ProcedureT

The research procedure consists of 4 stages, that were (Fauzi 2019; Tandio et al. 2022, 2023):

1. The initial stage of the research was carried out by surveying the research location with field observations and literature studies.
2. The data collection stage by conducting interviews directly with respondents using a questionnaire to analysis relation between stakeholders.
3. The data analysis stage is done by tabulating the data in Microsoft Excel to get mode data from the results of the questionnaire assessment followed by analyzing the data using MACTOR software.
4. The data classification stage is by grouping data based on the influence and dependence between stakeholders presented in the form of matrices and maps.
5. MACTOR analysis was conducted to determine the involvement of actors concerning the activity object. A table listing important actors along with their roles, strategic issues, and objectives of interest was created. From the first analysis, Actor Objectives were obtained in the 1MAO matrix. Subsequently, the following were generated: 1a) Convergence and divergence matrix 1 (1MAA), 2a) Convergence and divergence matrix 2 (2MAA), 3a) Convergence and divergence matrix 3 (3MAA), 1b) Value matrix (2MAO), 2b) Position matrix values and weighting, 3b) Strategic recommendations.
6. Actors are affected by direct and indirect power matrices and power coefficients. The steps of identifying and analyzing the interests of actors were done with MACTOR software. MACTOR works by filling in the position matrix or 1MAO (Actor-Objective Matrix) matrix and 2MAO matrix. After that, the next matrix to be completed is the MID matrix (Direct Influence Matrix) which describes the influencing variables. After filling in the MID and 1MAO matrices, MACTOR will calculate the 2MAO matrix through a computer program. Through the 3MAO matrix, various features can be generated, including mobilization coefficients, which show the various actors involved in a situation.
7. In addition to using a prospective analysis approach, this study also formulated the results of FGDs with stakeholders directly related to the development of mangrove areas Segara Anakan Lagoon, Cilacap in mapping the opinions of main stakeholders, key stakeholders, and supporting stakeholders involved in the FGD.

D. Data Analysis

Data analysis used quantitative descriptive analysis methods and stakeholders' analysis using MACTOR software. This analysis using MACTOR software employed many stakeholder groups which is shown in Table 1.

The analysis of stakeholder impact on mangrove management was analyzed using the relationship among stakeholders with objective mangrove management activities. The objective of mangrove management is shown in Table 2.

III. RESULTS AND DISCUSSION

A. The Role of Stakeholders in Mangrove Ecosystem Management in Segara Anakan Lagoon, Cilacap

The data in Table 3 shows that there are various activities of stakeholders to conserve, protect, manage, and other activities in the mangrove ecosystem in Segara Anakan.

Table 1. Stakeholders of mangrove management

No.	Long Label	Short Label
1.	Environment and Forestry Service of Central Java Province	DLHK Prov
2.	Cilacap District Environment Agency	Dinas LH
3.	Cilacap Regency Marine and Fisheries Agency	Dinas KP
4.	Donan and Kutawaru Village Governments	Village's
5.	Jenderal Soedirman University	Academics
6.	PT. Pertamina (Persero) RU IV Cilacap	Pertamina
7.	PT. Solusi Bangun Indonesia Tbk Cilacap	PT SBI
8.	Ecotourisme management	Ecotourism
9.	Community leaders	Com. leader
10.	Fishermen	Fishermen
11.	Fishpond farmers	Fishpond's
12.	Local community	Community
13.	Ship Crossing Transportation Services	Ships Boat
14.	Mangrove Crafts and Processed Products Maker	Craftsmen
15.	Silvofishery society	Silvofishr
16.	Agent of Fish and mangrove collectors	Fish_agent
17.	Non-government organizations	NGO
18.	Direct Mangrove Utilizers	Utilizers

Table 2. Objectives of mangrove management

No	Long label	Short label
1.	Management of mangrove forest areas	Forest
2.	Conservation of the mangrove ecosystem	Conserve
3.	Fishing ground management	Fish ground
4.	Habitat management for biota or wildlife	Habitat
5.	Mangrove rehabilitation	Rehabilitate
6.	Control of heavy metal, petroleum, and domestic water pollution	Pollution
7.	Improved clean water supply	Freshwater
8.	Mangrove ecosystem preservation efforts	Preserve
9.	Ecotourism development in mangrove ecosystems	Ecotourism
10.	Increased crab catches	Crabs
11.	Improved economy with fishpond business	Fishpond
12.	Increased shellfish catch	Shellfish
13.	Increased ship and boat transportation income	Boats ship
14.	Innovation of mangrove crafts or preparations	Craft innovate
15.	Management of silvofishery system	Silvofishery
16.	Continuity of fish catch supply	Fish catch
17.	Controlling mangrove land conversion	Conversion
18.	Prohibition of mangrove logging	Logging

Table 3. Identification of the role of each stakeholder

No.	Stakeholders	The role
1.	Environment and Forestry Service of Central Java Province	Formulate policies and evaluate the implementation of policies of Segara Anakan Lagoon, Cilacap mangrove area at the provincial level.
2.	Environmental Service of Cilacap Regency	Conducting guidance and supervision of the implementation of mangrove ecosystem management in Segara Anakan Lagoon, Cilacap.
3.	Marine and Fisheries Service of Cilacap Regency	Formulating policies, managing, and evaluating in the field of capture fisheries, aquaculture, and fisheries business of the mangrove ecosystem in Segara Anakan Lagon, Cilacap.
4.	Donan and Kutawaru Village Government	Establish development policies and management licenses carried out in the village area around the mangrove ecosystem in Segara Anakan Lagoon, Cilacap.
5.	Academics (Jenderal Soedirman University)	Contributing ideas and thoughts in the management of the mangrove ecosystem through research activities carried out in Segara Anakan Lagoon, Cilacap.
6.	PT. Pertamina (Persero) RU IV Cilacap	Conduct corporate social responsibility CSR activities to support environmental conservation in the form of mangrove planting and contribute to the development of facilities and infrastructure contained in ecotourism.
7.	PT. Solusi Bangun Indonesia Tbk Cilacap	CSR activities that contribute to the development of ecotourism facilities and infrastructure, facilitate mangrove batik business groups and conduct mangrove planting programs.
8.	Ecotourism Managers	Conducting ecotourism management and developing ecotourism areas by beautifying the location.
9.	Community Leaders	Contribute thoughts and ideas for the development of villages around mangrove ecosystems.
10.	Fisherman	Utilizing mangrove ecosystem resources by catching fish, shellfish, crabs, etc.
11.	Fish Farmers	Developing fisheries businesses with aquaculture activities in ponds.
12.	Local Communities	Participate in preserving the mangrove ecosystem.
13.	Boat Crossing Transportation Services	Providing ferry services for the community around the mangrove ecosystem.
14.	Mangrove Handicraft and Processed Makers	Utilizing mangrove ecosystem resources by innovating such as making flour and food from mangroves fruits, and handicrafts in the form of mangrove batik.
15.	Silvofishery Communities	Conducting aquaculture business by combining fisheries with mangrove planting.
16.	Fish Collectors	Parties that buy fisheries products from fishermen.
17.	Non-Governmental Organizations (NGOs)	Contribute to community empowerment.
18.	Direct Mangrove Users	Utilizing mangrove ecosystem resources directly such as mangrove wood utilization.

The results showed that there are about 18 stakeholder groups that play a role in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap, which are grouped into the government, the private sector, academics, and the community. These stakeholders have direct and indirect influence on mangrove ecosystem management. Based on the roles played, the stakeholders can be classified into three groups, namely main stakeholders, key stakeholders, and supporting stakeholders (Fauzi, 2019; Muawanah et al., 2020; Tandio et al., 2023).

The main stakeholders in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap consist of ecotourism managers, community leaders, fishermen, fish farmers, local communities, boat crossing transportation services, mangrove processed craftsmen, silvofishery communities, fish collectors, non-governmental organizations, and mangrove users directly. The groups of main stakeholders are those that can be directly impacted both positively and negatively by mangrove ecosystem management (Azman et al., 2021; Hilmi et al., 2017; Kantharajan et al., 2018; Shah & Ramesh, 2022). This shows that these parties are highly dependent on the existence of mangrove ecosystems in Segara Anakan Lagoon, Cilacap as their main livelihood (Fauzi, 2019; Muawanah et al., 2020; Tandio et al., 2023). Tandio et al. (2022, 2023) write that the management of the mangrove ecosystem in North Jakarta is influenced by eleven stakeholders.

Meanwhile, key stakeholders in the management of mangrove ecosystems in Segara Anakan Lagoon, Cilacap are the Central Java Provincial Environment and Forestry Office, the Cilacap Regency Environment Office, the Cilacap Regency Marine and Fisheries Office, and the Donan Village and Kutawaru Village Governments. Key stakeholders are stakeholders who have official authority in decision-making (Fauzi, 2019; Muawanah et al., 2020; Tandio et al., 2023), including in mangrove ecosystem management at the provincial, district, and village levels. In Segara Anakan Lagoon, the authority to manage mangrove areas no longer belongs to the local government but has shifted to the provincial authority, namely the Central Java Provincial Environment and Forestry Service and Perum Perhutani Central Java Regional Division (Fatimah et al., 2022; Fauzi, 2019; Junaidi, Hilmi, Madusari, & Williansyah, 2022; Muawanah et al., 2020; Tandio et al., 2023).

Supporting stakeholders in the management of mangrove ecosystems in Segara Anakan Lagoon, Cilacap consists of academics (universities, schools, and pesantren), PT. Pertamina (Persero) RU IV Cilacap, and PT. Solusi Bangun Indonesia Tbk Cilacap. These parties are those who have great concern and have contributed indirectly to the management of mangrove ecosystems in Segara Anakan Lagoon, Cilacap. The data also explained that the academics have a role to support mangrove conservation in Segara Anakan Lagoon, Cilacap with the activity of research, and collaboration with the private sector to do socialization of mangrove rehabilitation and conservation and mangrove ecotourism. The private sector (PT. Pertamina (Persero) RU IV Cilacap and PT. Solusi Bangun Indonesia Tbk Cilacap) also has activities to support mangrove conservation through Corporate Social Responsibility (CSR) programs. Some examples of stakeholder activities are ecotourism activities in Kutawaru Village, namely SIMANJA (Jagapati Mangrove Conservation) tourism fostered by PT Pertamina Patra Niaga Integrated Terminal Cilacap and Kampung Kecrabing Tourism Village fostered by PT Pertamina (Persero) RU IV Cilacap. Meanwhile, PT Solusi Bangun Indonesia Tbk Cilacap fosters the Batik Mangrove Joint Business Group (KUB). These supporting stakeholders can act as facilitators of ongoing programs and can influence decision-making (Hariyadi, 2018; Hilmi, Sari, Cahyo, Amron, et al., 2021; Rachman, 2020; Wardoyo, 2019). Research from (Tandio et al., 2023) reported that DPRD DKI Jakarta, the Ministry of Environment and Forestry of the Republic of Indonesia, the Bureau of Development and Environment of DKI Jakarta Province the Mayor of North Jakarta City, and the Government of DKI Jakarta Province have high influenced to support the sustainable of mangrove management in North of Jakarta.

B. Relationship Between Stakeholders in Supporting Mangrove Ecosystem Management in Segara Anakan Lagoon, Cilacap

Figure 2 shows that the Central Java Provincial Environment and Forestry Service

MDII	DLHK Prov	DinasLH	DinasKP	Village's	Academics	Pertamina	PT SBI	Ecotoursim	Com.leader	Fishermen	Fishpond's	Community	Ships Boat	Craftsmen	Silvofishr	Fish_agent	NGO	Utilizers	Ii
DLHK Prov	22	26	25	26	20	18	21	38	33	33	28	46	29	32	33	29	34	39	510
DinasLH	21	24	22	24	19	17	19	30	30	28	23	37	26	29	27	26	29	32	439
DinasKP	19	21	24	23	18	14	16	31	30	32	24	39	25	25	27	30	30	34	438
Village's	17	18	19	22	16	15	16	25	27	27	26	33	26	24	26	23	23	28	389
Academics	19	21	21	23	18	15	16	27	25	28	24	31	25	26	26	24	27	30	408
Pertamina	16	17	20	18	15	16	18	30	27	28	24	34	28	28	26	25	23	30	407
PT SBI	14	14	19	16	14	16	17	27	24	25	22	31	26	26	22	22	20	27	365
Ecotoursim	18	19	19	26	19	18	21	34	30	30	27	43	26	29	30	31	30	34	450
Com.leader	15	17	18	22	17	16	17	29	30	28	25	34	26	24	26	26	25	31	396
Fishermen	13	14	19	15	11	10	10	18	19	26	20	24	21	19	20	20	19	22	294
Fishpond's	8	8	14	10	9	8	8	16	18	21	16	21	19	15	16	18	14	20	243
Community	19	20	23	21	14	15	18	36	31	31	26	46	29	30	29	33	29	33	437
Ships Boat	10	12	17	14	9	9	9	23	24	23	20	30	21	19	21	20	17	23	300
Craftsmen	9	9	7	10	8	10	13	19	16	17	14	20	16	19	16	16	14	16	230
Silvofishr	6	6	8	9	7	8	8	14	15	17	14	17	16	14	14	13	13	16	201
Fish_agent	4	5	10	12	8	6	6	14	16	19	15	20	13	10	15	17	17	16	206
NGO	16	17	22	21	16	17	17	27	26	27	24	35	25	24	25	24	26	31	394
Utilizers	6	6	8	9	7	7	8	17	12	13	11	16	13	13	11	12	13	14	182
Di	230	250	291	299	227	219	241	421	403	427	367	511	389	387	396	392	377	462	6289

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Figure 2. Matrix of influence and dependence between stakeholders

(DLHK Prov. Central Java) has the highest influence on other stakeholders with an influence value of (Ii=510), while those with the greatest dependence on other stakeholders are local communities (Masyarakat) with a dependence value of (Di=511). This shows that the Department of Environment and Forestry of Central Java Province (DLHK Prov. Central Java) has the highest authority in the management of mangrove ecosystems in Segara Anakan Lagoon, Cilacap, including in terms of licensing and policy making. Meanwhile, local communities are the affected parties of mangrove area management policies that are highly dependent on the existence of mangrove ecosystems as their main livelihood. The results also showed that local communities are the main stakeholders who are the main objects of government policy (Fauzi, 2019; Tandio et al., 2023; Triyanti & Susilowati, 2019).

The stakeholders' influence and dependency map is a graph of the position, dependency, and influence between one actor and another (direct influence and indirect influence) analyzed with MACTOR software. The strength of influence and the level of dependence of stakeholders in MDII are described according to their location in the quadrant, with the concept that the higher position of the actor, the stronger the influence, while the more to the right the actor has a high dependence (Fauzi, 2019; Kalsum et al., 2022; Mahardika, Yulianda, Adrianto, & Sulistiono, 2022; Tandio et al., 2023; Triyanti & Susilowati, 2019). The map of influence and dependency between stakeholders in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap can be seen in Figure 3.

Figure 3 shows that the Central Java Provincial Environment and Forestry Service (DLHK Prov. Central Java), Cilacap Regency Marine and Fisheries Service (Dinas KP), Cilacap Regency Environmental Service (Dinas LH), Donan Village and Kutawaru Village Governments (Village Governments), Jenderal Soedirman University (Academics), PT. Pertamina (Persero) RU IV Cilacap (Pertamina), and PT. Solusi Bangun Indonesia Tbk Cilacap (PT. SBI) are dominant key stakeholders because they have the highest influence and can influence other stakeholders with a low level of dependence (quadrant I/top left). Stakeholders in this position are very important as policy designers, directing the implementation and evaluation of policies applied in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap. All stakeholders in Quadrant I have a strong influence and low dependence on the mangrove ecosystem management scenario in Segara Anakan Lagoon, Cilacap.

Ecotourism managers (PEkowisata), community leaders (TokohMsy), local communities (Masyarakat), and non-governmental organizations (NGOs) are relay stakeholders (quadrant II/top right)

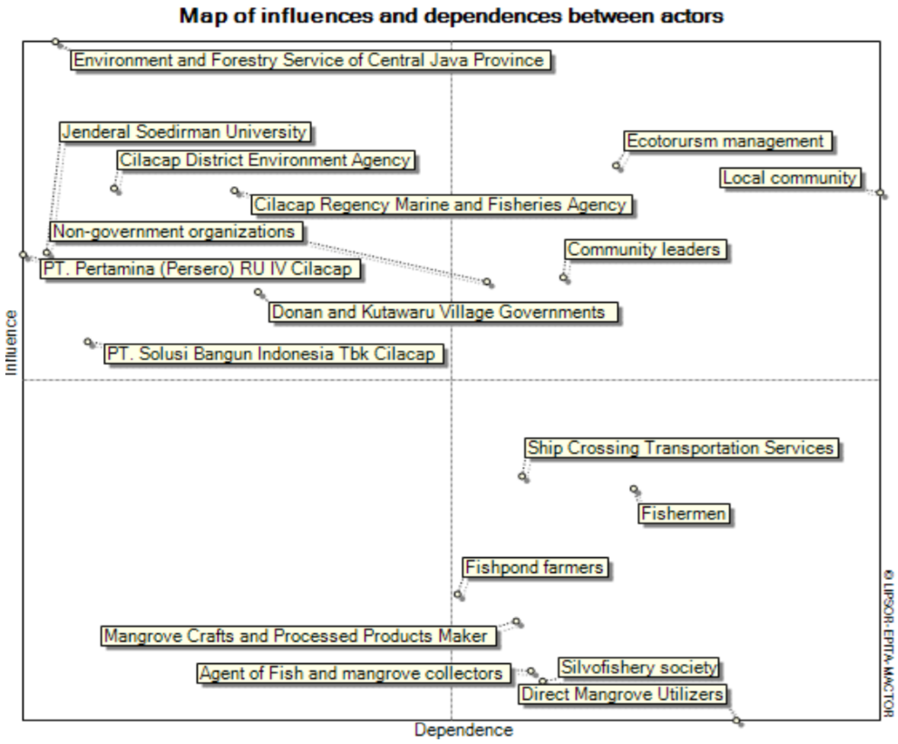


Figure 3. Map of influence and dependence between stakeholders

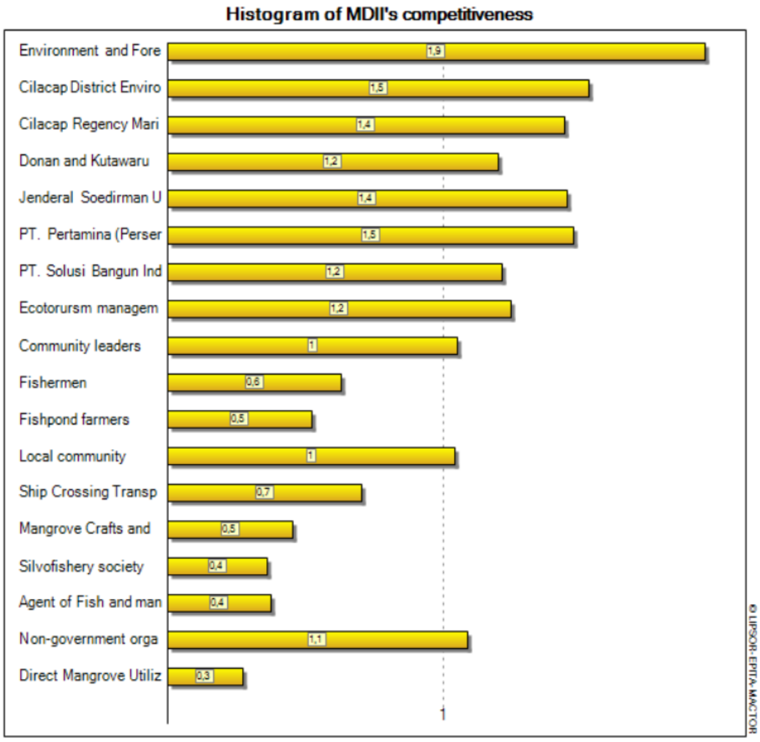
because the power of influence is high but the dependence is also high. Stakeholders who are in this position will spearhead and determine the success of the implementation of mangrove ecosystem management activities in Segara Anakan Lagoon, Cilacap tailored to their respective capacities and roles. Stakeholders in this position are also referred to as relay stakeholders. Stakeholder relay depends on stakeholders who are encouraged in Quadrant I, but have a significant influence on Quadrant III through the influence of Quadrant I stakeholders on Quadrant II stakeholders (Fauzi, 2019; Mahardika et al., 2022; Tandio et al., 2023; Wardono et al., 2019).

The ship and boats transportation service (TransKapal), fishermen (Fishermen), fish farmers (Cultivators), fish collectors (Collectors), mangrove handicraft makers and preparations (Craftsmen), silvofishery communities (MsySilvofi) and direct mangrove users (Beneficiaries) are stakeholders who are the object of mangrove management activities (quadrant III/bottom right). This indicates that these stakeholders are highly influenced and dependent on other stakeholders. Stakeholders who are in this position have a low level of power but have a high level of dependence on other stakeholders (Fauzi, 2019; Mahardika et al., 2022; Tandio et al., 2023; Wardono et al., 2019). The more upward actor has a high influence, while the more to the right actor has a high dependence (Mahardika et al., 2022; Tandio et al., 2023; Wardono et al., 2019).

C. Competitiveness between Stakeholders in Segara Anakan Lagoon

The diagram of the competitiveness of stakeholders in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap is shown in Figure 4. The competitiveness between stakeholders explains the role of stakeholders in supporting mangrove conservation in SAL (Tandio et al., 2022). The number of MDII (matrix direct influence) competitiveness also shows the direct influence of stakeholders to support the mangrove conservation in SAL.

Figure 4 shows that the stakeholders that play an important role both directly and indirectly



	Ri
DLHK Prov	1,95
DinasLH	1,53
DinasKP	1,44
Village's	1,20
Academics	1,45
Pertamina	1,47
PT SBI	1,21
Ecotoursim	1,24
Com.leader	1,05
Fishermen	0,63
Fishpond's	0,52
Community	1,04
Ships Boat	0,70
Craftsmen	0,46
Silvofishr	0,36
Fish_agent	0,38
NGO	1,09
Utilizers	0,27

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Figure 4. Histogram of competitiveness between stakeholders

are the Central Java Provincial Environment and Forestry Service (DLHK Prov. Central Java) (1.95), the Cilacap Regency Environment Service (DinasLH) (1.53), the Cilacap Regency Marine and Fisheries Service (DinasKP) (1.44), Donan Village Government and Kutawaru Village Government (Village Government) (1.20), Jenderal Soedirman University (Academician) (1.45), PT. Pertamina (Persero) RU IV Cilacap (Pertamina) (1.47), PT. Solusi Bangun Indonesia Tbk. Cilacap (PT. SBI) (1.21), ecotourism managers (Ecotourism Managers) (1.24), community leaders (Community Leaders) (1.05), community (Community) (1.04), and non-governmental organizations (NGOs) (1.09). Meanwhile, stakeholders who have weak competitiveness are fishermen (Fishermen) (0.63), fish farmers (Cultivators) (0.52), ship crossing transportation services (TransKapal) (0.70), mangrove craftsmen and preparations (Craftsmen) (0.46), silvofishery communities (MsySilvofi) (0.36), fish collectors (Collectors) (0.38), and direct mangrove users (Beneficiaries) (0.27). This is by the reference which states that stakeholders who have a value of more than 1 (100%) have high competitiveness and conversely stakeholders who have a value of less than 100% have low competitiveness dependence (Mahardika et al., 2022; Tandio et al., 2023; Wardono et al., 2019). Different from these results, Tandio et al. (2023) and (Tandio et al., 2022) reported that the Regional Peoples Representative Council, Ministery of Environment and Forestry, Jakarta Environment Department Burau, and local government of Jakarta have a high role in supporting the conservation and management of the mangrove ecosystem in North Jakarta.

D. The convergence and correlation between key stakeholders in Segara Anakan Lagoon

Figure 5 shows that 17 stakeholders support the 18 objectives that have been formulated indicated by the number (+1) and there is 1 stakeholder who does not support 5 of the 18 formulated objectives indicated by the number (-1). This shows that direct users of mangroves are more concerned with achieving economic goals than sustainability goals. This should

1MAO	Forest	Conservs	Fish_groun	Habitat	Rehabilita	Pollution	Freshwater	Preserve	Ecotoursm	Crabs	Fishpond	Shellfish	Boats ship	Craft inov	Silvofishe	fish catch	Conversion	logging	Absolute sum
DLHK Prov	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
DinasLH	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
DinasKP	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Village's	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Academics	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Pertamina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
PT SBI	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Ecotoursim	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Com.leader	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Fishermen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Fishpond's	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Community	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Ships Boat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Craftsmen	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Silvofishr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Fish_agent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
NGO	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Utilizers	-1	-1	1	-1	1	1	1	-1	1	1	1	1	1	1	1	1	1	-1	18
Number of agreements	17	17	18	17	18	18	18	17	18	18	18	18	18	18	18	18	18	17	
Number of disagreements	-1	-1	0	-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	-1	
Number of positions	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	

Figure 5. Valence level matrix of stakeholders to goals

2CAA	DLHK Prov	DinasLH	DinasKP	Village's	Academics	Pertamina	PT SBI	Ecotoursim	Com.leader	Fishermen	Fishpond's	Community	Ships Boat	Craftsmen	Silvofishr	Fish_agent	NGO	Utilizers
DLHK Prov	0,0	55,0	55,0	53,0	52,0	49,5	49,5	55,0	46,5	50,5	46,5	54,0	44,5	44,0	46,0	46,5	50,5	32,5
DinasLH	55,0	0,0	55,0	53,0	52,0	49,5	49,5	55,0	46,5	50,5	46,5	54,0	44,5	44,0	46,0	46,5	50,5	32,5
DinasKP	55,0	55,0	0,0	53,0	52,0	49,5	49,5	55,0	46,5	50,5	46,5	54,0	44,5	44,0	46,0	46,5	50,5	33,5
Village's	53,0	53,0	53,0	0,0	50,0	47,5	47,5	53,0	44,5	48,5	44,5	52,0	42,5	42,0	44,0	44,5	48,5	32,5
Academics	52,0	52,0	52,0	50,0	0,0	46,5	46,5	52,0	43,5	47,5	43,5	51,0	41,5	41,0	43,0	43,5	47,5	31,0
Pertamina	49,5	49,5	49,5	47,5	46,5	0,0	44,0	49,5	41,0	45,0	41,0	48,5	39,0	38,5	40,5	41,0	45,0	30,0
PT SBI	49,5	49,5	49,5	47,5	46,5	44,0	0,0	49,5	41,0	45,0	41,0	48,5	39,0	38,5	40,5	41,0	45,0	30,0
Ecotoursim	55,0	55,0	55,0	53,0	52,0	49,5	49,5	0,0	46,5	50,5	46,5	54,0	44,5	44,0	46,0	46,5	50,5	34,5
Com.leader	46,5	46,5	46,5	44,5	43,5	41,0	41,0	46,5	0,0	42,0	38,0	45,5	36,0	35,5	37,5	38,0	42,0	27,5
Fishermen	50,5	50,5	50,5	48,5	47,5	45,0	45,0	50,5	42,0	0,0	42,0	49,5	40,0	39,5	41,5	42,0	46,0	30,0
Fishpond's	46,5	46,5	46,5	44,5	43,5	41,0	41,0	46,5	38,0	42,0	0,0	45,5	36,0	35,5	37,5	38,0	42,0	29,0
Community	54,0	54,0	54,0	52,0	51,0	48,5	48,5	54,0	45,5	49,5	45,5	0,0	43,5	43,0	45,0	45,5	49,5	34,5
Ships Boat	44,5	44,5	44,5	42,5	41,5	39,0	39,0	44,5	36,0	40,0	36,0	43,5	0,0	33,5	35,5	36,0	40,0	27,0
Craftsmen	44,0	44,0	44,0	42,0	41,0	38,5	38,5	44,0	35,5	39,5	35,5	43,0	33,5	0,0	35,0	35,5	39,5	26,5
Silvofishr	46,0	46,0	46,0	44,0	43,0	40,5	40,5	46,0	37,5	41,5	37,5	45,0	35,5	35,0	0,0	37,5	41,5	27,5
Fish_agent	46,5	46,5	46,5	44,5	43,5	41,0	41,0	46,5	38,0	42,0	38,0	45,5	36,0	35,5	37,5	0,0	42,0	26,5
NGO	50,5	50,5	50,5	48,5	47,5	45,0	45,0	50,5	42,0	46,0	42,0	49,5	40,0	39,5	41,5	42,0	0,0	30,0
Utilizers	32,5	32,5	33,5	32,5	31,0	30,0	30,0	34,5	27,5	30,0	29,0	34,5	27,0	26,5	27,5	26,5	30,0	0,0
Number of convergences	830,5	830,5	831,5	800,5	784,0	745,5	745,5	832,5	698,0	760,5	699,5	817,5	667,5	659,5	690,5	697,0	760,5	515,0
Degree of convergence (%)	96,1																	

Figure 6. Convergence matrix between stakeholders

get attention from the government so that the achievement of economic goals is balanced with sustainability goals. Disagreement with sustainability goals by direct mangrove users (Beneficiaries), indicates the need for intensive socialization and efforts to increase awareness of the importance of mangrove ecosystem conservation in Segara Anakan Lagoon, Cilacap to realize sustainable mangrove.

The next analysis is the Actor and Actor Convergence Matrix (2CAA). This matrix calculates the average intensity of convergence between two stakeholders when they have the same level (pro or contra to the goal). The following convergence matrix between stakeholders (2CAA) in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap is presented in Figure 6

Figure 6 also shows that the Central Java Provincial Environment and Forestry Service (DLHK Prov. Central Java), the Cilacap Regency Environmental Service (DinasLH), and the Cilacap Regency Marine and Fisheries Service (DinasKP) with ecotourism managers (PEkowisata) have the same interest with an intensity coefficient of 55.0. This shows that the

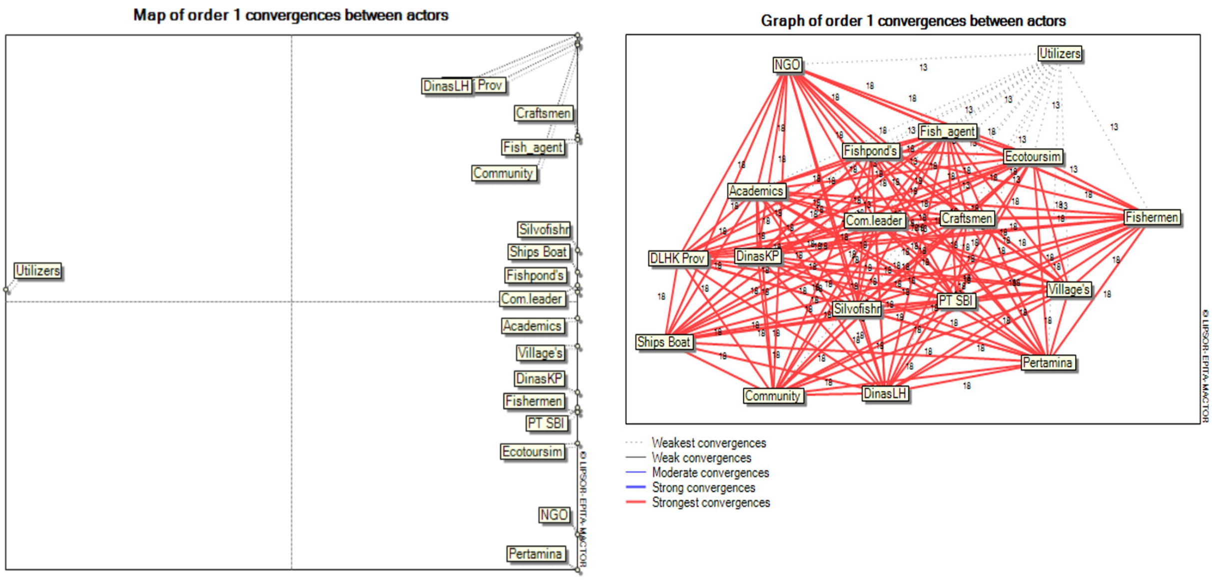

Figure 7a. Graph of convergence between stakeholders (Order 1)

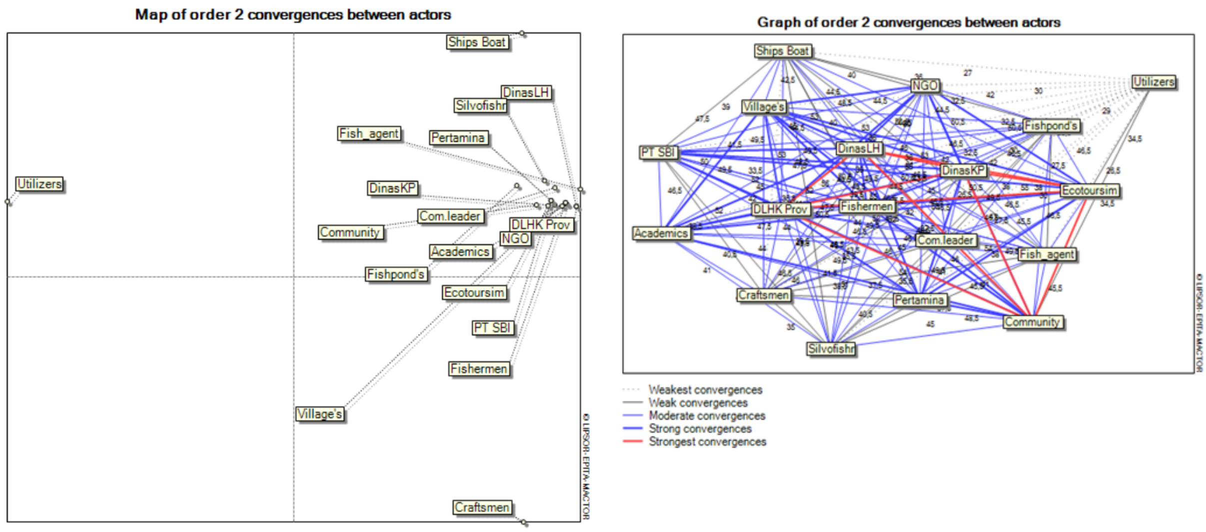

Figure 7b. Graph of convergence between stakeholders (Order 2)

level of stakeholder interest and cooperation is very strong. The stakeholder pair that has the highest value indicates the high intensity of the pair's relationship toward achieving goal dependence (Mahardika et al., 2022; Tandio et al., 2023; Wardono et al., 2019). The degree of convergence in SAL was 96.1% and the degree of convergence above 79% indicates that the possibility of conflict is relatively low (Fauzi, 2019; Mahardika et al., 2022; Tandio et al., 2023).)

Figures 7a and 7b show the strongest convergence between stakeholders in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap, indicated by the red line. Starting from the Central Java Provincial Environment and Forestry Service (DLHK Prov), the Cilacap Regency Environment Service (DinasLH), the Cilacap Regency Maritime and Fisheries Service (DinasKP) to ecotourism managers (PEkowisata), and the local community (Masyarakat) indicated

3MAO	Forest	Conservs	Fish_groun	Habitat	Rehabilita	Pollution	Freshwater	Preserve	Ecotoursm	Crabs	Fishpond	Shellfish	Boats ship	Craft inov	Silvofishe	fish catch	Conversion	logging	Mobilisation
DLHK Prov	7,8	7,8	5,8	7,8	7,8	5,8	7,8	7,8	3,9	3,9	3,9	3,9	3,9	3,9	7,8	3,9	5,8	7,8	107,0
DinasLH	6,1	6,1	4,6	6,1	6,1	4,6	6,1	6,1	3,1	3,1	3,1	3,1	3,1	3,1	6,1	3,1	4,6	6,1	84,1
DinasKP	4,3	4,3	5,8	5,8	5,8	2,9	4,3	5,8	2,9	5,8	2,9	4,3	2,9	2,9	5,8	4,3	2,9	5,8	79,1
Village's	3,6	2,4	2,4	3,6	4,8	2,4	3,6	4,8	3,6	2,4	2,4	2,4	3,6	3,6	4,8	2,4	3,6	4,8	61,2
Academics	4,3	4,3	2,9	4,3	5,8	4,3	5,8	5,8	2,9	2,9	1,4	2,9	2,9	2,9	4,3	2,9	4,3	5,8	71,0
Pertamina	4,4	2,9	2,9	4,4	5,9	4,4	4,4	4,4	5,9	2,9	1,5	2,9	1,5	4,4	4,4	1,5	1,5	4,4	64,7
PT SBI	3,6	2,4	2,4	3,6	4,9	3,6	3,6	3,6	4,9	2,4	1,2	2,4	1,2	3,6	3,6	1,2	1,2	3,6	53,4
Ecotoursim	5,0	2,5	3,7	3,7	5,0	3,7	3,7	3,7	5,0	3,7	1,2	3,7	5,0	5,0	5,0	1,2	2,5	5,0	68,4
Com.leader	3,1	2,1	2,1	2,1	3,1	2,1	2,1	3,1	2,1	2,1	2,1	2,1	1,0	2,1	3,1	1,0	1,0	3,1	39,9
Fishermen	1,9	1,3	2,5	2,5	1,9	1,9	1,9	1,9	1,3	1,9	0,6	1,9	0,6	0,6	0,6	2,5	0,6	2,5	29,1
Fishpond's	1,0	1,0	1,0	1,0	1,6	1,0	1,6	1,0	1,0	1,6	2,1	1,6	0,5	0,5	0,5	0,5	1,0	1,0	19,9
Community	3,1	2,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1	4,2	3,1	3,1	3,1	2,1	3,1	55,3
Ships Boat	1,4	1,4	1,4	1,4	2,1	1,4	1,4	1,4	2,8	0,7	0,7	0,7	2,8	0,7	0,7	0,7	0,7	1,4	23,9
Craftsmen	0,9	0,9	0,9	0,9	1,4	0,9	1,4	0,9	0,9	0,5	0,5	0,5	0,5	1,8	0,5	0,5	0,5	0,9	15,0
Silvofishr	0,7	0,7	0,7	1,1	1,1	1,1	1,1	0,7	0,7	0,7	0,4	0,4	0,4	0,4	1,5	0,4	0,4	1,1	13,5
Fish_agent	0,8	1,1	1,5	1,5	0,8	0,8	0,8	0,8	0,4	0,8	0,4	0,4	0,4	0,4	0,4	1,5	0,4	1,5	14,3
NGO	3,3	3,3	2,2	4,4	4,4	3,3	4,4	3,3	3,3	2,2	2,2	2,2	2,2	2,2	2,2	1,1	1,1	3,3	50,0
Utilizers	-0,8	-1,1	0,5	-0,5	0,8	1,1	0,8	-1,1	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	-1,1	12,9
Number of agreements	55,5	46,8	46,7	57,5	66,2	48,5	57,9	58,3	48,2	41,2	30,2	39,0	37,1	41,7	55,0	32,4	34,8	61,3	
Number of disagreements	-0,8	-1,1	0,0	-0,5	0,0	0,0	0,0	-1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-1,1	
Degree of mobilisation	56,3	47,9	46,7	58,0	66,2	48,5	57,9	59,4	48,2	41,2	30,2	39,0	37,1	41,7	55,0	32,4	34,8	62,4	

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Figure 8. Matrix of Weighted Values of Stakeholders' Position against Objectives

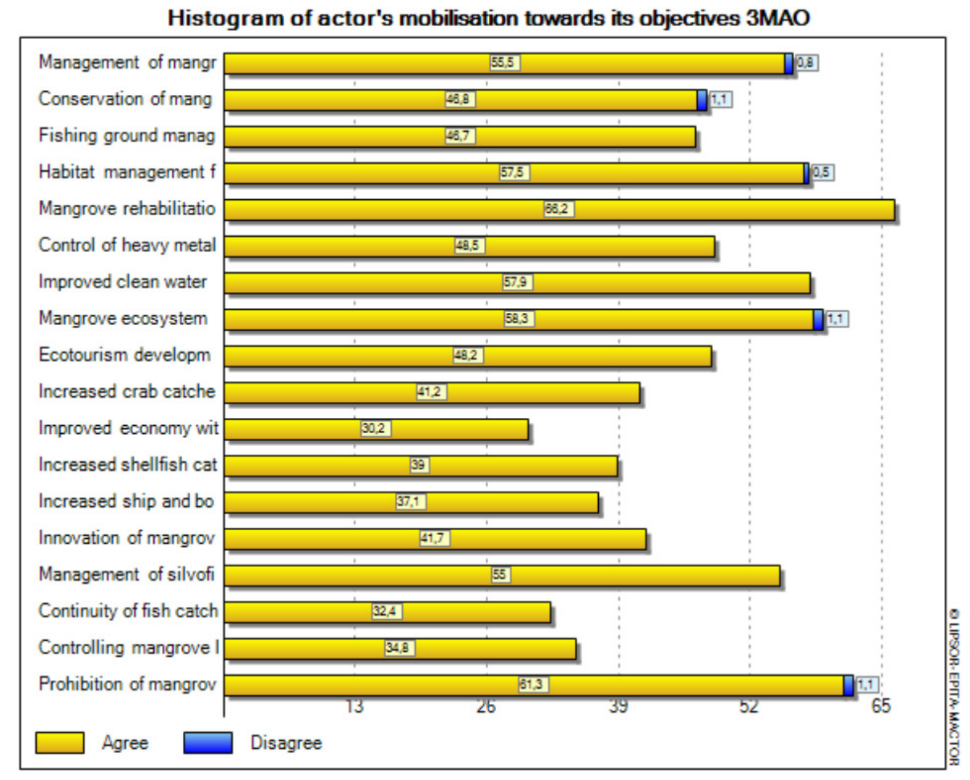

Figure 9. Histogram of Stakeholders' Mobility to Objectives

by thick red arrows with convergence values of 55.0 and 54.0 respectively. The role and participation of the community are very important in the formulation of policies by the government in management, starting from planning, implementation, and evaluation to realize sustainable management (Mahardika et al., 2022; Pace et al., 2023; Saptutyningsih et al., 2020). The role of the central and local governments is needed, especially for ecosystem user communities through extension activities, socialization, and dialogue to get input on ideas and common perceptions related to mangrove ecosystem management (Mahardika et al., 2022; Tandio et al., 2023; Triyanti & Susilowati, 2019; Wardono et al., 2019) (Figure 8).

2DAA	DLHK Prov	DinasLH	DinasKP	Village's	Academics	Pertamina	PT SBI	Ecotoursim	Com.leader	Fishermen	Fishpond's	Community	Ships Boat	Craftsmen	Silvofishr	Fish_agent	NGO	Utilizers
DLHK Prov	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	18,5
DinasLH	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	18,5
DinasKP	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	17,5
Village's	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	16,5
Academics	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	17,0
Pertamina	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	15,5
PT SBI	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	15,5
Ecotoursim	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	16,5
Com.leader	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	15,0
Fishermen	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	16,5
Fishpond's	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13,5
Community	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	15,5
Ships Boat	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13,5
Craftsmen	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	13,5
Silvofishr	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	14,5
Fish_agent	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	16,0
NGO	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	16,5
Utilizers	18,5	18,5	17,5	16,5	17,0	15,5	15,5	16,5	15,0	16,5	13,5	15,5	13,5	13,5	14,5	16,0	16,5	0,0
Number of divergences	18,5	18,5	17,5	16,5	17,0	15,5	15,5	16,5	15,0	16,5	13,5	15,5	13,5	13,5	14,5	16,0	16,5	270,0
Degree of divergence (%)	3,9																	

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Figure 10. Weighted Divergence Value Matrix Between Stakeholders

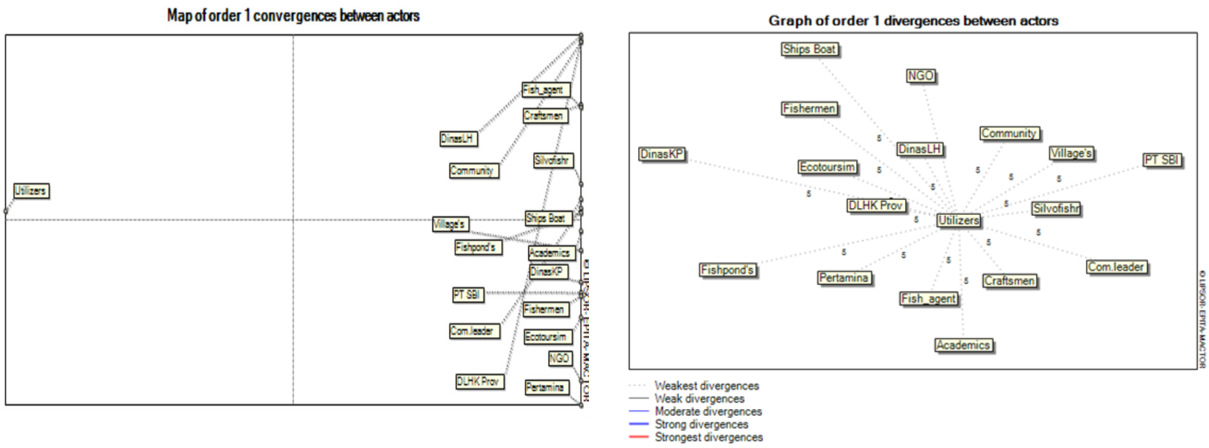


Figure 11a. Graph divergence between stakeholders (Order 1)

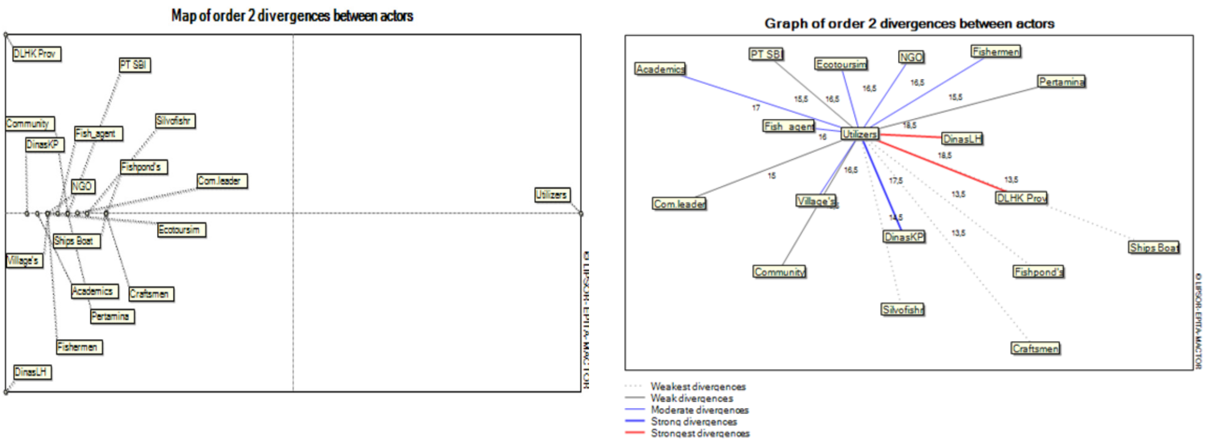
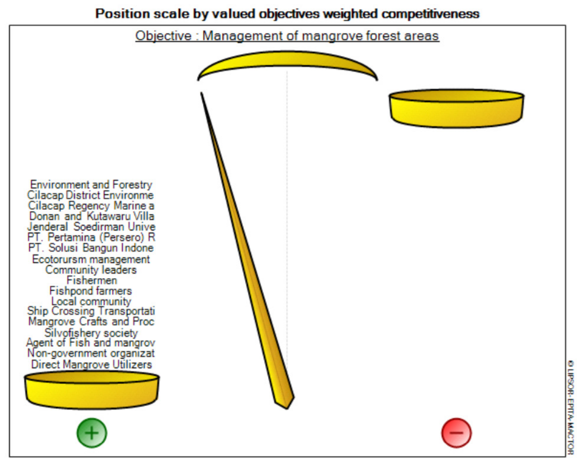


Figure 11b. Graph divergence between stakeholders (Order 2)

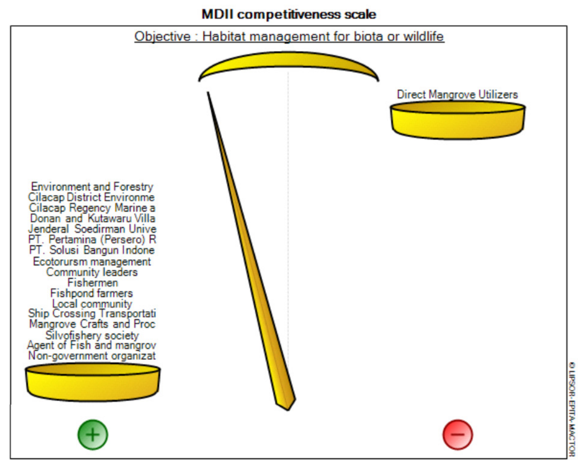
The 3MAO matrix also shows that the most active stakeholders in this activity are the Central Java Provincial Environment and Forestry Service (DLHK Prov. Central Java) and the Cilacap Regency Environmental Service (DinasLH) with mobility values of 107.0 and 84.1, respectively. The mobilization level of 66.2 (bottom row) shows that rehabilitation of the degraded mangrove ecosystem is the goal that gets the most attention from the stakeholders. This can be seen in Figure 9, where the mobilization level of 66.2 is fully supported by the agreement of the stakeholders. This is because the stakeholders feel the importance of degraded mangrove ecosystem rehabilitation (Rhblitasi). All stakeholders provide support for mangrove ecosystem rehabilitation activities in Segara Anakan Lagoon, Cilacap.

The analysis of the level of divergence between stakeholders in Figure 10 shows the level of divergence between stakeholders presented in the form of a Valued Divergence Matrix (2DAA). The highest divergence value is owned by direct mangrove users (Beneficiaries) with a value of 270.0. This indicates that direct mangrove users (Beneficiaries) have the greatest potential for conflict with other stakeholders. However, the overall degree of divergence is shown at 3.9% which indicates that there is no potential conflict from the activities of the stakeholders because the value of the degree of divergence is still lower than 20% (Fauzi, 2019; Mahardika et al., 2022; Tandio et al., 2023).

Figures 11a and 11b also show a visualization of the divergence between stakeholders. The strongest divergence occurs between the Central Java Provincial Environment and Forestry Service (DLHK Prov. Central Java) and the Cilacap Regency Environmental Service (DinasLH) with direct mangrove users (Beneficiaries) which are marked with a thick red line and the divergence value found in direct mangrove users (Mangrove users) is 18.5.



Objectives: Management of Fishing Areas; Rehabilitation of Damage to Mangrove Ecosystems; Control of Water Pollution Due to Heavy Metals, Petroleum and Domestic; Improvement of Clean Water Supply; Development of Mangrove Ecotourism; Improvement of Crab Catches; Improvement of the Pond Economy; Improvement of Shellfish Catches; Increased Revenue for Transportation and Ferry Services; Innovation in Crafts or Processing of Fishery Products; Management of Fishery Lands using Silvofishery Systems; Continuity of Catch Supply; Controlling of Mangrove Land Use Change



Objectives: Mangrove forest management, Mangrove Ecosystem Conservation, Biota or Animal Habitat Management, Mangrove Ecosystem Preservation Efforts, Mangrove Logging Prohibition

Figure 12. The influent scale of key stakeholders with objectives

E. The influent scale of key stakeholders with the objective

This analysis of MACTORs uses "scales" for each objective. The following are the "scales" for each objective presented in Figure 12. Figure 12 shows that of the 18 objectives that have been formulated, there are pros and cons among stakeholders. Thirteen objectives were fully supported by stakeholders, namely the management of fishing grounds (Catch), rehabilitation of the damaged mangrove ecosystem (Rehabilitation), control of water pollution due to heavy metals, petroleum, and domestic (Pollution), increased availability of clean water (Water Supply), development of ecotourism in mangrove ecosystems (Ecotourism), increased crab catch (Crab), economic improvement with ponds (Ponds), increased catches of shellfish (Shellfish), increased income of boat crossing transportation services (Ships), innovation of mangrove crafts or processing (Crafts), management of fishery land with silvofishery system (Silvofishery), sustainability of catch supply (Supply), and control of mangrove land conversion (Land). However, there 5 objectives that are not fully supported by stakeholders which are the management of mangrove forest areas (Forest), preservation of mangrove ecosystems (Conservation), management of biota or animal habitats (Habitat), efforts to preserve mangrove ecosystems (Sustainable), and prohibition of mangrove forest logging (Logging) (Hariyadi, 2018; Sari, 2016).

Stakeholders that support the formulated goals/objectives are the Environmental and Forestry Service (DLHK Prov), the Cilacap Regency Environmental Service (DinasLH), the Marine and Fisheries Service (DinasKP), the Donan Village and Kutawaru Village Governments (PemDes), Jenderal Soedirman University (Academics), PT. Pertamina (Persero) RU IV Cilacap (Pertamina), PT. Solusi Bangun Indonesia Tbk Cilacap (PT. SBI), ecotourism managers (Ecotourism Managers), community leaders (Community Leaders), fishermen (Fishermen), fish farmers (Cultivators), local communities (Communities), ship crossing transportation services (TransKapal), craftsmen and mangrove preparations (Craftsmen), silvofishery communities (MsySilvofi), fish collectors (Collectors), and non-governmental organizations (NGOs). Meanwhile, stakeholders who disagree with the formulated objectives are direct mangrove users (Beneficiaries). Parties that are pro to the goal have an awareness of the importance of the sustainability of mangrove ecosystems in Segara Anakan Lagoon by paying attention to activities that support the sustainability of mangrove ecosystems, while the direct mangrove users prioritize goals that lead to profit or income so that it contradicts the goal of sustainability. Utilization of mangrove areas for rice fields, ponds, and illegal logging as part of human activities to gain benefits for their survival (Fatimah et al., 2022; Hariyadi, 2018; Yulianti & Ariastita, 2012).

Figure 13 illustrates the distance relationship between objectives in mangrove ecosystem management in SAL. It can be seen that the goal of rehabilitation of degraded mangrove ecosystem (Rehabilitation) with increased water supply (Water Supply) and the prohibition of mangrove logging (Logging) with mangrove ecosystem conservation efforts (Lestari) and management of biota or animal habitat (Habitat) has the strongest relationship, which is marked with a thick red line. This shows that the goal of rehabilitation of degraded mangrove ecosystems (Rehabilitation) can support the success of the goal of increasing the availability of clean water (Water Supply). The goal of mangrove ecosystem conservation efforts (Lestari) and management of biota or animal habitats (Habitat) will support the success of the goal of prohibiting mangrove logging (Logging) (Azman et al., 2021; Datta & Deb, 2017; Murniasih, Hendarto, & Hilm, 2022; Sidik, Lawrence, Wagey, Zamzani, & Lovelock, 2023).

Figure 14 provides an overview of the relationship between stakeholders in the management of mangrove ecosystems in

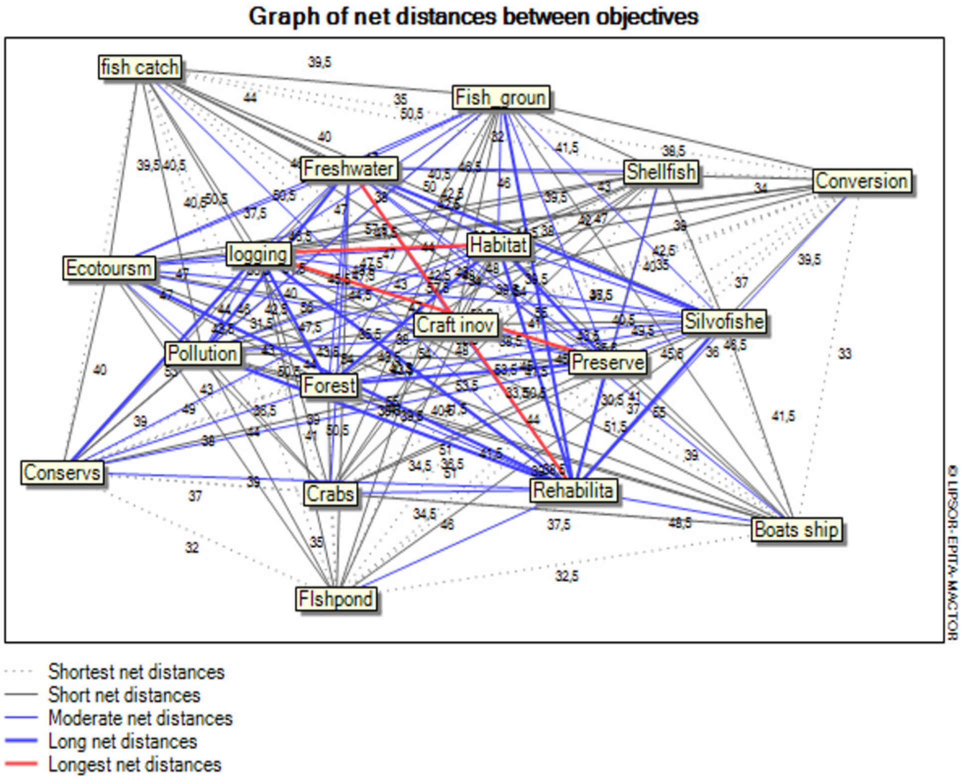


Figure 13. Graph of net distance between objectives

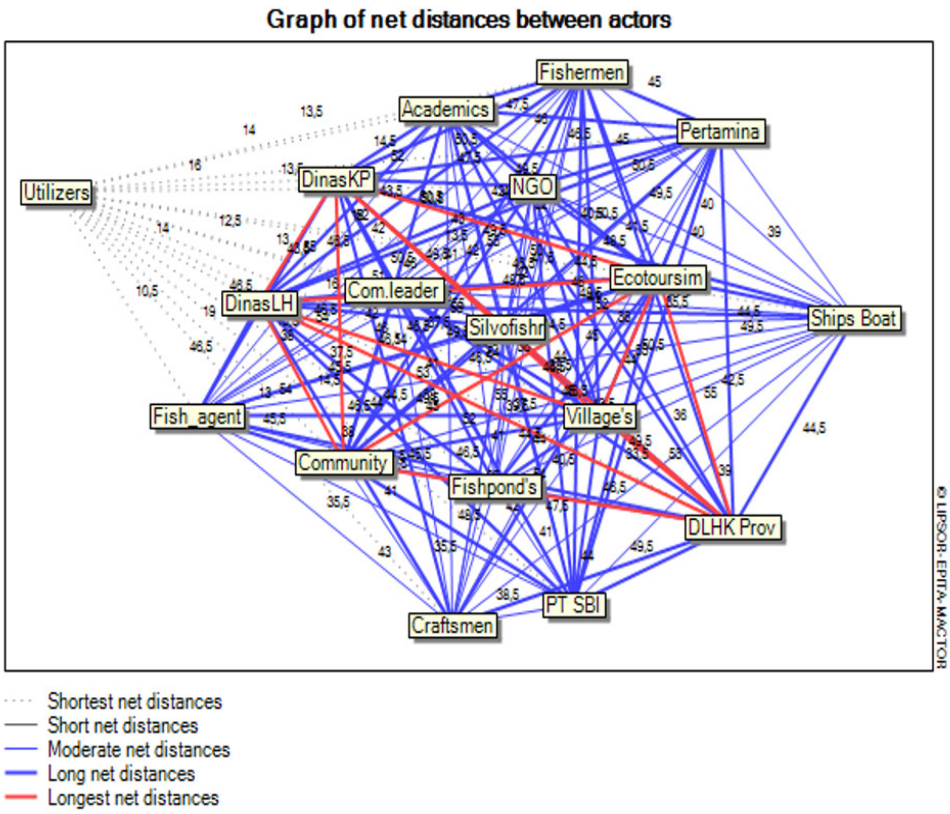


Figure 14. Graph of net distance between stakeholders

Segara Anakan Lagoon, which shows the existence of linkages between the Central Java Provincial Environment and Forestry Service (DLHK Prov. Central Java), the Cilacap Regency Environment Office (DinasLH), the Cilacap Regency Maritime and Fisheries Service (DinasKP), the Village Government (PemDes) Donan and Kutawaru, ecotourism managers (PEkowisata), local communities (Masyarakat), silvofishery communities (MsySilvofi), and the strongest are non-governmental organizations (NGOs). The relationship between stakeholders is shown with a thick red line. This shows that there is mutually beneficial cooperation between stakeholders in preserving the mangrove ecosystem in Segara Anakan Lagoon, Cilacap.

IV. CONCLUSION

Segara Anakan Lagoon, Cilacap has 18 stakeholders who have different roles in supporting the management activities of the mangrove ecosystem. The relationship between stakeholders in mangrove ecosystem management in Segara Anakan Lagoon, Cilacap is indicated by the value of the degree of convergence and divergence. The degree of convergence is 96.1% which indicates that the possibility of conflict between stakeholders is relatively small, while the degree of divergence is 3.9% which indicates the potential for conflict that can occur. The positive objectives to support mangrove conservation and management were the Management of Fishing Areas; Rehabilitation of Degraded Mangrove Ecosystems; Control of Water Pollution Due to Heavy Metals, Petroleum, and Domestic; Improvement of Clean Water Supply; Development of Mangrove Ecotourism; Improvement of Crab Catches; Improvement of the Pond Economy; Improvement of Shellfish Catches; Increased Revenue for Transportation and Ferry Services; Innovation in Crafts or Processing of Fishery Products; Management of Fishery Lands using Silvofishery Systems; Continuity of Catch Supply; Controlling of Mangrove Land Use Change.

Based on the role of stakeholders, the mangrove ecosystem management in Segara Anakan Lagoon, Cilacap requires the big role of the Central Java Provincial Environment and Forestry Office, the Cilacap Regency Environment Office, the Cilacap Regency Marine and Fisheries Office, and the Donan Village and Kutawaru Village Governments as the key stakeholders; meanwhile, Jenderal Soedirman University, PT. Pertamina RU IV Cilacap, and PT. Solusi Bangun Indonesia Tbk. Cilacap, as the supporting stakeholders to support mangrove conservation in Segara Anakan Lagoon, Cilacap, also plays big roles in the SAL mangrove ecosystem management.

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THE ROLE OF STAKEHOLDERS AND EXOGENOUS VARIABLES AFFECTING THE OUTCOME OF SOCIAL FORESTRY POLICIES IN CENTRAL SULAWESI, INDONESIA

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THE ROLE OF STAKEHOLDERS AND EXOGENOUS VARIABLES AFFECTING THE OUTCOME OF SOCIAL FORESTRY POLICIES IN CENTRAL SULAWESI, INDONESIA. Social forestry (SF) is Indonesian policy that aims to provide legal access to the community in utilizing forest resources and seek sustainable forest management, contributing to the community's economic improvement. This study examines the action situation of implementing SF policies in Central Sulawesi Province and analyses the roles of stakeholders and exogenous variables determining SF policies' outcomes. The Institutional Analysis Development (IAD) framework was applied in the study by identifying and analyzing the action situation and its relation to the implementation of SF in Central Sulawesi. The research revealed that the implementation of social forestry in Central Sulawesi Province is not optimal. This is indicated by the fact that local institutions have not achieved self-governance, the sustainability of forest function has not been realized, and the social forestry programs have not significantly increased the income of the local community. Implementing the SF policy depends on the facilitator's capacity at the site level and stakeholders' support. The action for strengthening social forestry at site levels requires strong collaboration among stakeholders by considering their interests and capacities. These findings suggested the urgency of future research to examine strategies for governing the role of stakeholders in boosting local institutional capacity and the outcomes of SF policies.

Keywords: Community empowerment, local community, stakeholders' capacity, local institution

PERAN PEMANGKU KEPENTINGAN DAN VARIABEL EKSOGEN YANG MEMPENGARUHI HASIL KEBIJAKAN PERHUTANAN SOSIAL DI SULAWESI TENGAH, INDONESIA. Perhurtanan sosial (PS) merupakan kebijakan nasional yang bertujuan memberikan akses legal kepada masyarakat dalam memanfaatkan sumber daya hutan dan mewujudkan pengelolaan hutan lestari yang berkontribusi pada peningkatan ekonomi masyarakat. Studi ini mengkaji situasi aksi implementasi kebijakan PS di Provinsi Sulawesi Tengah dan menganalisis peran pemangku kepentingan dan variabel eksogen dalam menentukan kinerja kebijakan PS. Kerangka Institutional Analysis Development (IAD) digunakan dalam penelitian ini dengan mengidentifikasi dan menganalisis situasi aksi dan kaitannya dengan implementasi PS di Sulawesi Tengah. Hasil penelitian mengungkapkan bahwa situasi aksi pelaksanaan perhutanan sosial di Provinsi Sulawesi Tengah belum optimal yang ditunjukkan oleh kelembagaan lokal yang belum self-governing, kelestarian fungsi hutan belum terwujud, dan program perhutanan sosial belum memberikan kontribusi yang signifikan bagi peningkatan pendapatan masyarakat lokal. Implementasi kebijakan perhutanan sosial tergantung pada kapasitas fasilitator di tingkat lokasi dan dukungan pemangku kepentingan. Aksi penguatan perhutanan sosial pada tingkat lokal memerlukan strategi kolaboratif melalui penataan peran para pemangku kepentingan dengan mempertimbangkan kepentingan dan kapasitasnya. Penelitian ini menguatkan pentingnya penelitian lanjutan untuk mengkaji strategi penataan peran stakeholder dalam meningkatkan kapasitas kelembagaan lokal dan kinerja PS.

Kata kunci: Pemberdayaan masyarakat, masyarakat local, kapasitas para pihak, kelembagaan lokal

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I. INTRODUCTION

One of the priority programs of the Government of the Republic of Indonesia is to achieve economic independence by driving strategic sectors of the domestic economy, including the forestry sector. In this regard, the Government of the Republic of Indonesia is committed to allocating at least 12,7 million ha of forest area for the development of sharing schemes for Social Forestry (SF), including schemes for Community Plantation Forests (Hutan Tanaman Rakyat/HTR), Community Forests (Hutan Kemasyarakatan/HK), Village Forests (Hutan Desa/HD), Customary Forest (Hutan Adat/HA), and Forestry Partnership (Kemitraan Kehutanan/KK). Three pillars of social forestry policy objectives are 1) economic objectives, alleviating poverty of forest use by strengthening the community's livelihoods, 2) social objectives, conferring rights and authority and empowering the community to manage and control forest resources, 3) ecological objectives, improving ecological conditions and forest conservation (Charnley & Poe, 2007; Fisher et al., 2018; Maryudi et al., 2012).

The Republic of Indonesia's Government has issued many regulations to support the acceleration of social forestry in Indonesia. Recently, the government has just issued a regulation of the Minister of Environment and Forestry No. 9 of 2021, which explicitly regulates the management of social forestry. At the regional level, the Central Sulawesi provincial government has responded to the accelerating SF program's policy in the regional medium-term development plan, establishing a Working Group for SF acceleration, and facilitating activities for the institutional formation and licensing of forestry schemes.

In addition to the formal legal aspects of SF management approval, the SF policies require aspects of institutional capacity building that enable community groups around forests to enforce their rights and to gain benefit from forest resources for economic improvement while conserving forest resources (Suharjito & Purwawangsa, 2014). Without being supported by capacity building, providing access for the community to manage forests would threaten forest resource sustainability (Massiri et al., 2015). On the other side, local communities have no benefit from permit-based social forestry if their capacity is low (Ragandhi et al., 2021).

The SF policy is also a form of community empowerment in forest management (Asmin et al., 2019). The empowerment program's objective is to bring out a self-sufficient community having the capability to solve their problems and obtainbenefits from the forest resources. The effort to achieve local institutions' independence, particularly in the SF scheme is a challenge for the government (Massiri et al., 2020). Some government are challenging to transform local institutions into empowered entities (Anugrahsari et al., 2020).

Implementation of the SF policy involves multi-stakeholders (Fisher et al., 2018). The outcome of the SF policy is determined by many interrelated factors and is complex (Sahide, Fisher, Erbaugh, et al., 2020; Singh et al., 2011). Therefore it requires an approach to assessing its outcome. The role of stakeholders and their approach applied in the facilitation process affect the awareness, capacity, and responsibilities of forest farmers and individual targets in SF management (Sahide, Fisher, Supratman, et al., 2020). The boost of the local communities' capacity is highly dependent on the role of ground facilitators (Hastanti & Raharjo, 2021).

Studies on the implementation of SF policies have been conducted by many researchers, mainly in the western area of Indonesia. Research conducted by Rakatama & Pandit (2020) revealed that the implementation of SF policies varied but still has barriers on social and environmental aspects. Sahide, Fisher, Verheijen et al. (2020) emphasized that the actor's power is the central factor determining SF's outcome. Studies on the implementation of SF policies in Central Sulawesi Province have been less published, while the Local Government of

Central Sulawesi Province has programmed a target of achieving SF of 100,000 ha in five years.

The SF program is also one of the main concerns of the Regional Government of Central Sulawesi Province because it corresponds with the Governor of Central Sulawesi's vision and mission, namely the mission of realizing increased community welfare through empowering the people's economy and strengthening institutions, and the mission of maintaining harmony between humans and nature, as a form of sustainable development. This study examines the action situation of implementing SF policies in Central Sulawesi Province and analyzes the roles of stakeholders and exogenous variables determining SF policies' outcome, using the Institutional Analysis Development (IAD) framework (Ostrom, 2011).

II. THEORETICAL FRAMEWORK

Many interrelated factors determine SF's policy outcomes. In this study, complex factors are simplified by a systematic grouping approach in a framework to facilitate analysis, determine the relationship and influence, and find the key factors determining SF policy outcomes. The Institutional Analysis Development (IAD) Framework, formulated by Ostrom (2011), could be applied to examine the outcome of the policy. This framework provides a multi-level analysis and organizes the components that influence outcomes (McGinnis, 2011). This framework can also be applied to analyze institutions and policies in sustainable forest resource management (Araral & Amri, 2016; Carter et al., 2016).

The IAD framework components include a) exogenous variables, b) action situations, c) outcomes and evaluation criteria. Based on the IAD framework, two components determine the outcome: 1) the action situations and 2) exogenous variables. Ostrom (2011) emphasizes that the critical part of the IAD Framework is in action situations resulting in interaction and outcomes. The internal structure of an action situation consists of actors, positions, and actions. In this study, we use the term the roles of stakeholders to describe the internal structure of the action situations. The stakeholder approach focuses on the dimensions of power and interest, in contrast to actor analysis which explores in-depth, including examining networks, actor views, and interdependencies among actors (Enserink

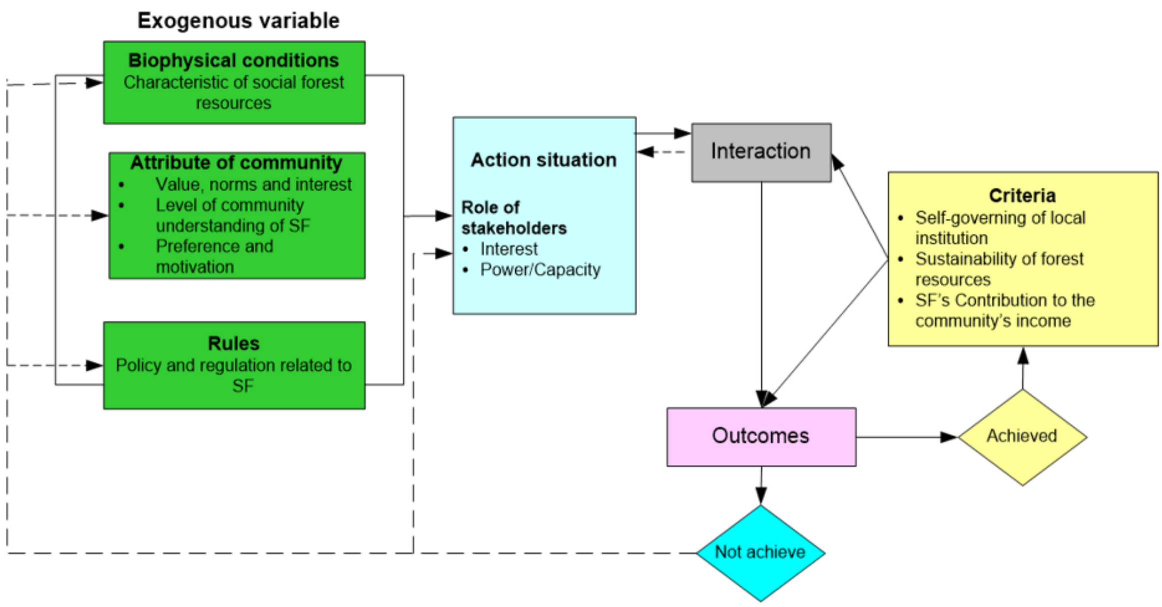


Figure 1. Theoretical Framework, Adapted from (Ostrom, 2011)

et al., 2010). Interests, in this context, include involvement in the program, the benefits of the program, how the program is organized, the readiness of stakeholders, and the suitability of the main tasks/rules. Meanwhile, power/capacity refers to the influence of authority, type of stakeholder policy, strategic resource power, expertise/specialization, and program sustainability.

The exogenous variables are inputs that form the action situations including biophysical conditions, community attributes, and rules (McGinnis, 2011). Biophysical conditions refer to resource characteristics. While characteristics of resources are related to market aspects, including the nature of excludable, subtractable, and transferable goods, which affect individual choices and actions (Ostrom, 2005).

The actions of individuals in society cannot be separated from the attributes of the community or systems in which they live. The attributes of community include a) values, norms, and interests of the community, b) level of community understanding of SF, and c) preference and motivation of community. Values, norms, and interests in society can become informal institutions that order community interactions, including their interactions with forest resources. These informal institutions can support but also hinder the performance of formal institutions (Claver & Knocking, 2015). Furthermore, rules in use include policies and regulations related to social forestry, both at the government and at the local level (community level), which also simultaneously affect the interaction and performance of SF.

The outcome of the SF acceleration policy is assessed through three criteria, namely; 1) self-governing of local institutions, 2) forest resources sustainability, and 3) SF's contribution to the community's income. This outcome reflected the role of stakeholders in action situations in facilitating or empowering the local community of SF. The sustainability of forest resources is an ecological objective of SF that can be evaluated using land cover change analysis. Meanwhile, the economic aim of the SF is to contribute to the community's income, which can be assessed through business units established by community groups that promote community income. Subsequently, the self-governance institution is one of SF's social goals that can be evaluated using the design principle of long-enduring institutions (Ostrom, 1990). However, it needs to be adapted to the research context. In this study, the self-governance institution of SF was assessed through several indicators; a) active community participation, b) fairness in resource use, c) community attitudes to the forest, d) the role of local institutions in planning and regulating forest resource use, e) role of local institutions in monitoring forest, f) the role of local institutions in applying local sanctions, g) the role of local institutions in conflict resolution, and h) increasing institutional capacity.

III. MATERIALS AND METHODS

A. Study Site

This study examines 20 SF permits of Central Sulawesi Province, covering ten village forests (Hutan Desa/HD) and ten community forestry (Hutan Kemasyarakatan/HKM) distributed across 6 Regencies of Central Sulawesi Province. Determination of the locations of this study reflects the attribute of community and distribution of biophysical conditions as part of exogenous variables. The research location is presented in Figure 2.

B. Methods

Data for this study were collected in 2018. The method of data collection included field observation, structured interviews with respondents, in-depth interviews, Focus Group Discussion (FGD) with SF group members, and study documentation. Structured interviews were conducted with 30 respondents from each of the 20 SF groups to collect data on the impact of SF on community economic improvement and communities' dependence

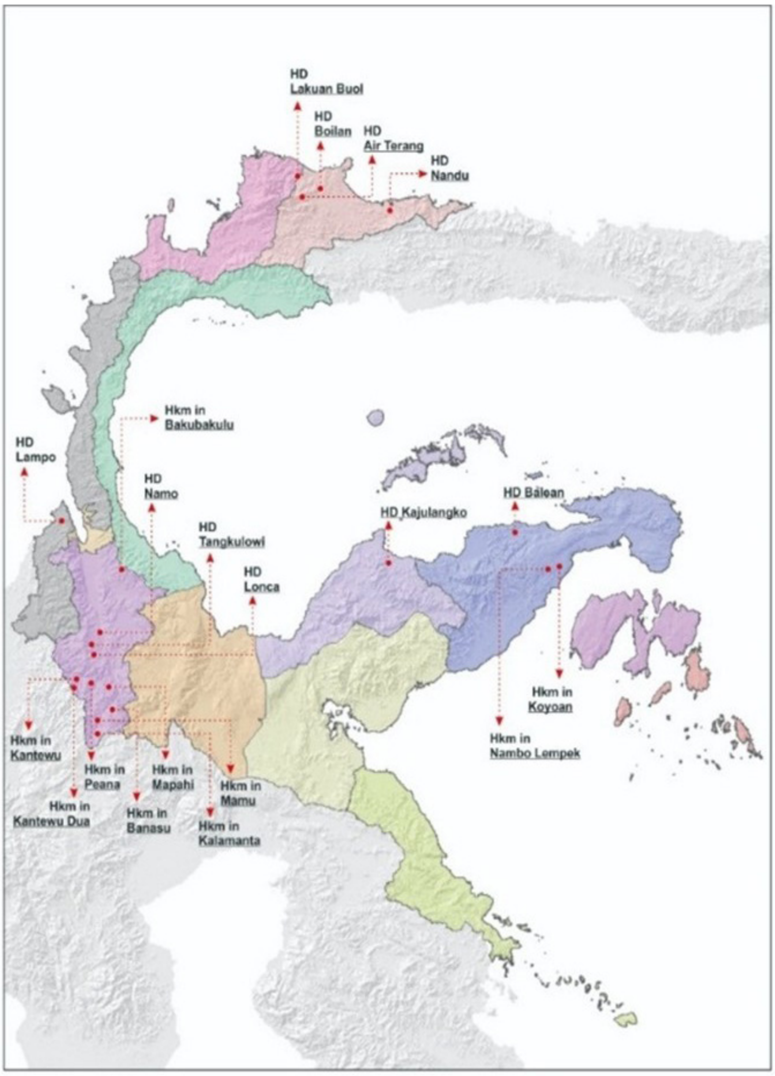


Figure 2. The research Location

on forest resources. These Respondents were randomly selected from SF group members. In-depth interviews with key informants were conducted to collect the action situation data of the implementation of the SF acceleration policy and the self-governing of local institutions. Informants in this study were stakeholders involved in implementing SF policies in Central Sulawesi Province, including the SF acceleration working group, field facilitators, and group managers of village forest and community forestry. Field observations were carried out to study forest cover, encroachment activity, and forest resources condition of SF. This research also conducted document studies on regulations, activity reports, and supporting data on related government agencies, village governments, and other supporting data related to SF.

C. Analysis

This study applied the IAD framework to classify and identify relationships among components, and data analysis was carried out at each component level that affects the outcome of SF policy. This study applied qualitative and quantitative data analysis based on each study's components. The requirements data and analysis methods are presented in Table 1.

Table 1. Data requirements and analysis methods

Variables	Data Requirements	Data collection techniques	Analysis Methods
The impact of SF on community economic improvement	▪ The existence of the SF business unit ▪ Performance of the SF business ▪ Increase in community income ▪ Income comparability ▪ Contribution of SF utilization business income to household income	Interview with respondents	Descriptive analysis ▪ Income analysis $\pi = TR - TC$ ▪ Income comparability $t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$ ▪ Contribution to household income $P_{(x)} = \frac{P_2 - P_1}{P_1} x\ 100\%$
The impact of SF on forest sustainability	▪ Forest cover change ▪ Encroachment intensity	Imagery analysis and field observation Imagery analysis, field observation, and interviews with respondents	▪ Land cover analysis ▪ Descriptive analysis of encroachment
The impact of SF on the self-governing of local institutions	▪ Local community participation ▪ Equity in the use of forest resources ▪ attitudes in supporting forest sustainability ▪ the role of local institutions in planning and regulating the use of forest resources. ▪ the role of a local institution in forest monitoring ▪ the role of a local institution in graduated sanction ▪ the role of a local institution in conflict resolution ▪ institutional capacity	Focused group discussion, in-depth interview with respondents	▪ Institutional analysis ▪ Likert scale; 1= low, 2 = moderate, 3 = high. ▪ Category self-governing of local institutions is figured from the mode value.
action situation	▪ Support of the stakeholder ▪ Facilitation for institutional precondition process ▪ The planning process	in-depth interview	▪ Qualitative descriptive analysis
Exogenous Variable	▪ Forest resources condition ▪ Communities' dependence on forest resources ▪ Policy and regulation related to SF	Interview with respondents, and observation Interview using a questionnaire Secondary data	▪ Descriptive analysis ▪ Descriptive analysis ▪ Content Analysis

IV. RESULT AND DISCUSSION

A. The Action Situation of SF in Central Sulawesi

The SF policy was set as one of the priority programs of the Central Sulawesi provincial government in the forestry sector since 2017. The Regional Government of Central Sulawesi Province has planned the SF Program into the Regional Medium-Term Development Plan of Central Sulawesi. The SF target of the Central Sulawesi provincial is to issue SF permits covering an area of 100.000 hectares within five years, as presented in Table 2.

Based on this target, most SF submissions have received approval from the Minister of Environment and Forestry. As of December 2023, a total of 188 locations, covering an area of 113.769,81 hectares, already received

Table 2. Forest area allocation target for SF in Central Sulawesi

Description	Years				
	2017	**2018**	**2019**	**2020**	**2021**
Forest area allocation target for SF	20.000 Ha	40.000 Ha	60.000 Ha	80.000 Ha	100.000 Ha

Source: Regional planning of Central Sulawesi, 2017

Table 3. The progress of the SF permit in Central Sulawesi Province until 2023

Schemes	Number of Permits	Area (ha)
Customary Forest (*Hutan Adat/HA*)	6,00	17.501,00
Village Forest *(Hutan Desa/HD)*	78,00	62.560,32
Community Forest *(Hutan Kemasyarakatan/HKm)*	68,00	29.898,82
Community Plantation Forest *(Hutan Tanaman Rakyat /HTR)*	27,00	3.195,00
Forestry Partnership (*Kemitraan Kehutanan*)	9	614,67
Total	**188,00**	**113.769,81**

formal approval. These schemes involved the participation of 35.923 households belonging to forest community/farmer groups. The most widely developed SF schemes were village forests and community forestry. The progress of the SF permit in Central Sulawesi Province until 2023 is presented in Table 3.

Strategies and policies related to SF that were set in the Regional Medium-Term Development Plan of Central Sulawesi were intended to empower communities around forest areas and their capacity to manage SF by developing appropriate technology in forest management through various SF schemes. To achieve this target, the local government of Central Sulawesi has formed the Working Group for the Acceleration of Social Forestry (Kelompok Kerja Percepatan Perhutanan Sosial/Pokja PPS). Stakeholders involved in the working group include local apparatus organizations, the Forest Management Unit (FMU), the Technical organization of the Ministry of Environment and Forestry, non-governmental organizations, environmentalists, and academics.

The central government has a dominant authority and administrative control in deciding social forestry permits (Rakatama & Pandit, 2020; Tajuddin et al., 2019). In the Ministry of Environment and Forestry Regulation Number 9/2021, it was stated that the Central Government could delegate the approval for SF permits to the Governor, as long as the provincial government has included social forestry in the regional medium-term development plan, has a regional SF regulations, and has a regional revenue and expenditure budget of at least 35% of the total forestry budget for SF. The previous rule (P.83/2016) did not specify the minimum quantity required. The Regional Government of Central Sulawesi Province, consequently, was not granted a delegation with the authority to issue licenses. Local governments' sole authority is to participate in the technical verification of SF proposals.

The SF program development action in Central Sulawesi province involved stakeholders in the Working Group for the Acceleration of Social Forestry. Stakeholders who have a high role in facilitating FS development in Central Sulawesi province were Forest Services, FMU, and NGO. The roles of the stakeholders in the SF development actions in Central Sulawesi are described in Table 4.

Table 4. Stakeholders role in the development of SF in Central Sulawesi

Stakeholder	Roles in the development of SF	Level of roles
Forestry Services of Central Sulawesi	a, c, h	High
FMUs of Central Sulawesi	a, b, d, e, f, g, h	High
Technical implementation Unit of MoEF	a, c	Moderate
University	h	Moderate
NGO	b, e, f, g	High

Description: a = site preparation, b = group preconditions for SF licensing, c= verification of licensing proposals, d = facilitation of planning preparation both business management plans and annual management plans, e = facilitation and strengthening of the capacity of SF management groups, f = utilization and forest resource management, g = SF business development, h = monitoring and evaluation

The high interest of Forestry Services and FMUs in SF is due to the suitability to their main tasks. In addition, the head of the Forestry Service is the Chair of the working group for the Acceleration of SF in Central Sulawesi. The Forestry Service has the power to influence and sustain the program of SF and it has the role in site preparation, verification of licensing proposals, and monitoring and evaluation activities. Meanwhile, FMUs have a critical role in promoting community-based forest management (Massiri et al., 2020). The role of FMUs at the site level is also dominant in preparing the site for SF, group preconditions for SF licensing, facilitation of planning preparation for both business management plans and annual management plans, facilitating and strengthening the capacity of SF management groups, utilization and forest resource management, SF business development, and monitoring and evaluation.

The role of NGOs is also high in the action situation of preconditions for SF licensing, facilitation, and strengthening of the capacity of SF management groups, utilization, and forest resource management, and in SF business development. Some local NGOs had group strengthening programs, but many were not sustainable. Budi et al. (2021) also revealed that NGOs' dominant role could strengthen the capacity of SF local institutions.

B. The Outcome of The SF Program

Conceptually, the SF policy is expected to achieve three goals (Bong et al., 2019); 1) sustainability of forest resources with indicators of increasing forest land cover and decreasing deforestation and degradation, 2) equity, namely justice for rights and responsibilities, and benefits obtained from forest resources, 3) efficiency by supporting local needs and overcoming problems high enforcement cost of forest resources. It is in line with the concepts and indicators that we use in assessing the outcomes of the SF program, namely forest land cover, which is the ecological pillar of SF's goals, contribution to the local communities income, which is the economic pillar of SF's goals and self-governing of the local institution which is the social pillar of SF's goals.

1. Self-governing of the local institution

SF policy is a form of devolution in forest management (De Royer et al., 2018; Meijaard et al., 2021). The SF development policy's target is not only at the stage of completing community legal access to forest resources but also encouraging local communities to manage and utilize forest resources independently. That way, the SF development action is a series of community empowerment activities in forest management to realize the local institutions' autonomy (Erbaugh, 2019; Massiri, 2022).

This study revealed that the action situation of SF development generated varying outcomes for the SF management's institutional independence. The Village Forest Management Institution (LPHD) tended to be better than the HKm farmer groups. HKm farmer groups' institutional independence was in the low to

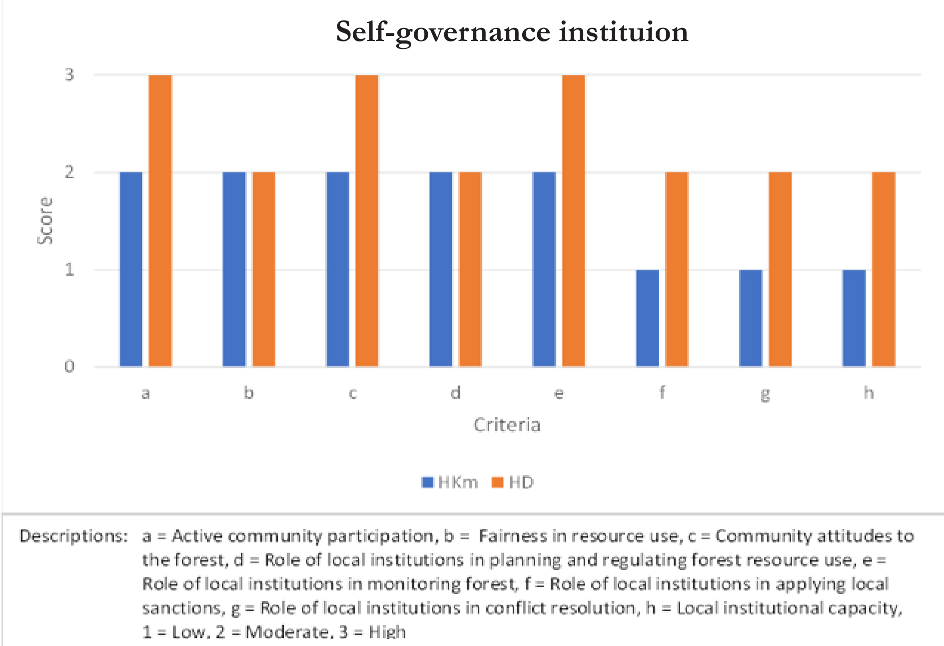


Figure 3. Institutional independence of SF

Table 5. Performance of Self-governance of HKm Groups

Indicator	HKm Group										Category
	HKm in Nambo Lempek Village	**HKm in Koyoan Village**	**HKm in Bakubakulu**	**HKm in Peana Village**	**HKm in Kantewu Village**	**HKm in Kantewu Dua Village**	**HKm in Mapahi Village**	**HKm in Banasu Village**	**HKm in Mamu Village**	**HKm in Kalamanta Village**	
Active community participation	1	1	2	2	2	2	2	2	2	2	Moderate
Fairness in resource use	1	1	1	2	2	2	2	2	2	2	Moderate
Community attitudes to the forest	1	1	1	2	2	2	2	2	2	2	Moderate
Role of local institutions in planning and regulating forest resource use	1	1	1	2	2	2	2	2	2	2	Moderate
Role of local institutions in monitoring forest	1	1	1	2	2	2	2	2	2	2	Moderate
Role of local institutions in applying local sanctions	1	1	1	1	1	1	1	1	1	1	Low
Role of local institutions in conflict resolution	1	1	1	1	1	1	1	1	1	1	Low
Local institutional capacity	1	1	1	1	1	1	1	1	1	1	Low
Score	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**Moderate**

Notes: 1= low, 2 = moderate, 3 = high category self-governing of local institutions is figured from the mode value.

medium category, while the LPHD institutional independence was generally in the medium to high category, except for HKm Nupabomba which hads not received any guidance or institutional strengthening programs.

This research revealed that the HKm group institution's roles were low in implementing sanctions, conflict resolution, and funding networks. The HKm group management's existence did not resolve conflicts, violations of regulations, and unable to provide funding to support forest management. It was found that several group managements did not understand their duties and functions in supporting forest management.

The HKm group management's weak role in carrying out forest management activities was related to resource characteristics as an exogenous variable that will determine the outcome. The characteristic of forest resources in the HKm area was quasi-private property, although de jure it is a state-owned forest area. The community's position in the forest area is as proprietor. In de facto, most of the forest areas that were granted the HKm permit have previously been controlled by the local community. The community had cultivated forest land to support their daily needs, even before it was granted a legal permit through HKm. In these resource characteristics, decisions on resource use were based on personal decisions.

The market aspect was the primary consideration for the community in determining land uses. The collective choice decision in groups did not work. Forest and land-use decisions were not determined by group decisions but were dominantly based on market-oriented personal decisions Therefore, forest management planning in HKm areas in Central Sulawesi should consider more market aspects that support the community's income and forest area sustainability.

In the context of Forest Village management, this study revealed that LPHD institutions in Central Sulawesi province could increase the community's participation in forest management, reinforce the communities' attitudes toward forest sustainability, and increase forest monitoring. However, this study also found that several LPHDs were not optimal in planning and regulating forest resource use, implementing sanctions for any violation, resolving conflicts, and providing funding.

Based on the institutional point of view, the characteristic of resources in HDs is a communal property managed by the village government. The local community has equal opportunities to utilize forest resources as arranged by the village forest management institution. The characteristics of this resource affect the outcome of institutional performance. The weakness that needs attention for common property is building internal agreements with community administrators and members,

Table 6. Performance of self-governance of HD Institution

Indicators	HD Scheme											Category
	HD Lakuan Boul	HD Air Terang	HD Boilan	HD Nandu	HD Lampo	HD Nupabomba	HD Lonca	HD Namo	HD Tongkulowi	HD Kajulangko	HD Balean	
Active community participation	1	3	3	1	3	1	3	3	2	2	3	High
Fairness in resource use	2	2	2	2	2	1	2	2	2	2	2	Moderate
Community attitudes to the forest	3	3	3	3	2	1	2	2	3	2	3	High
Role of local institutions in planning and regulating forest resource use	2	3	3	2	3	1	2	3	2	2	3	Moderate
Role of local institutions in monitoring forest	2	3	3	2	2	1	3	3	1	1	3	High
Role of local institutions in applying local sanctions	1	2	2	1	2	1	2	2	2	2	2	Moderate
Role of local institutions in conflict resolution	3	2	2	3	2	1	2	2	2	2	2	Moderate
Local institutional capacity	2	3	3	2	2	1	2	3	2	1	2	Moderate
Score	**2**	**3**	**3**	**2**	**2**	**1**	**2**	**3**	**2**	**2**	**3**	**Moderate**

Notes: 1= low, 2 = moderate, 3 = high. Category self-governing of local institutions is figured from the mode value.

especially if the number of village communities grows large. Therefore, it is necessary to strengthen local institutions. Strengthening the HD institutions that should be optimized is applying sanctions for violations and resolving conflicts at the local level independently. The capacity to apply local sanctions and resolve conflicts are prerequisites for realizing a self-governing institution (Massiri et al., 2019; Paudyal et al., 2017).

2. Land Cover Change in the SF Area

Deforestation and forest degradation are major problems encountered by forest managers in Indonesia. One of the SF program goals is to increase forest land cover or reduce deforestation and forest degradation through local communities' support However, this study found that deforestation and forest degradation still occurred in both HKm and FV areas. The deforestation and forest degradation in the HKm area is higher than in HD, as presented in Figure 4.

The forest degradation rate from 2016 to 2018 in HKm reached 6,12%, while HD was only 1,12%. Forest degradation in SF areas was higher than deforestation. The level of deforestation in the HKm area was 1,46%, while in the HD area it was 0,75%. Even though the deforestation and degradation levels tend to be different between HKm and HD, statistically, it was not significant. The local community was dependent on forest and land resources, while the institutional capacity of SF was weak, particularly in forest monitoring and graduating sanctions to violators. The action situation for strengthening the local institution's capacity of SF in the province of Central Sulawesi was still focused on the facilitation of permits but not yet on post-permit actions. The Dynamics of land cover in the SF areas are presented in Table 7 and Table 8.

Deforestation and forest degradation reflected the performance of institutions at the local level. This finding confirms that community-based forest management positively affects community subsistence, equity, and security, resulting in forest cover loss due to changing land functions (Harbi et al., 2020). This situation confirms that providing access without strengthening the institutional capacity at the local level has not significantly impacted forest sustainability. Providing access should be supported by strengthening the community's capacity both in terms of utilizing forest resources and in terms of regulating and protecting forests (Massiri et al., 2015).

In addition to deforestation and forest degradation which reduce forest areas' function, there was also an increase in land cover from alloy cropping and shrubs to the secondary forest in the HKm and HD areas. This situation occurred because some SF permit areas were not managed intensively and some areas were fallowed by the local community.

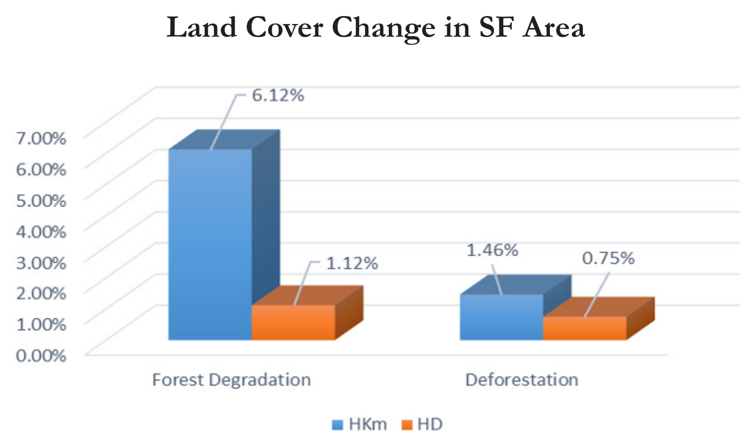


Figure 4. Land Cover Change in SF Area (Imagery analysis and field observation)

Table 7. Land cover dynamics in the HKm Area

Community Forestry	Land cover change			Situations
	Land use types in 2016	Land use types in 2018	Land Changes (Ha)	
HKm in villege of Nambo Lempek and Koyoan	Alloy cropping	Secondary forest	51,04	Reforestation
HKm Lestari Permai in the Bakubakulu village	Primary forest	Secondary forest	86,61	Degradation
	Primary forest	Alloy cropping	7,53	Deforestation
	Secondary forest	Alloy cropping	9,35	Deforestation
	Secondary Forest	Shrubs	37,72	Deforestation
HKm in Banasu Village	Primary forest	Secondary forest	55,63	Degradation
HKm in Mamu Village	Primary Forest	Secondary forest	16,75	Degradation
	Shrubs	Secondary forest	52,53	Fallowed to secondary forest
HKm in Kalamanta Village	Shrubs	Secondary forest	12,49	Fallowed to secondary forest

Table 8. Land use dynamics in the HD Area

Village Forest	Land Use Dynamics			Situations
	Land use types in 2016	Land use types in 2018	Land Changes (Ha)	
HD Lampo	Secondary forest	Dryland agriculture	24,34	Deforestation
HD Namo	Primary forest	Bare land	12,86	Deforestation
HD Lonca	Primary forest	Secondary forest	55,13	Degradation
HD Nupabomba	Primary forest	Secondary forest	13,36	Degradation
	Secondary forest	alloy cropping	25,83	Deforestation
HD Balean	Alloy cropping	Secondary forest	25,79	Fallow to Secondary forest

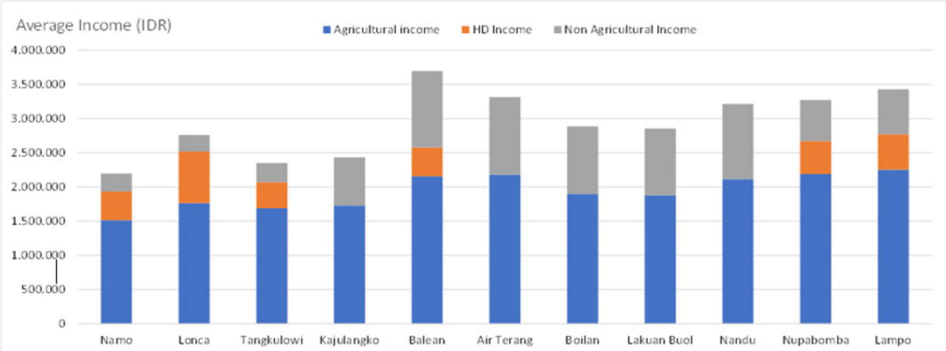
3. SF Contribution to Local Community Income

The purpose of providing legal access for the community to manage and utilize forest resources is to increase the community's income around the forest area. However, this research revealed that the SF program through the HD scheme has not contributed significantly to the income of local communities around forest areas. In contrast to the HKm scheme, land use in the HKm area has contributed significantly to HKm group members' income.

The average HD contribution in increasing the community income was only 9,43%. This low contribution had a close relation to the capacity of LPHD. Some HDs have not been managed and utilized, and most HD managers have no productive business units. The ability to benefit from resources is mediated by the bundle of powers that includes: access to technology, access to capital, access to the market, access to knowledge, and access to authority (Peluso & Ribot, 2020; Ribot & Peluso, 2003). Income contribution of the HD in Central Sulawesi Province which has carried out non-timber forest product utilization activities was 19,03%..

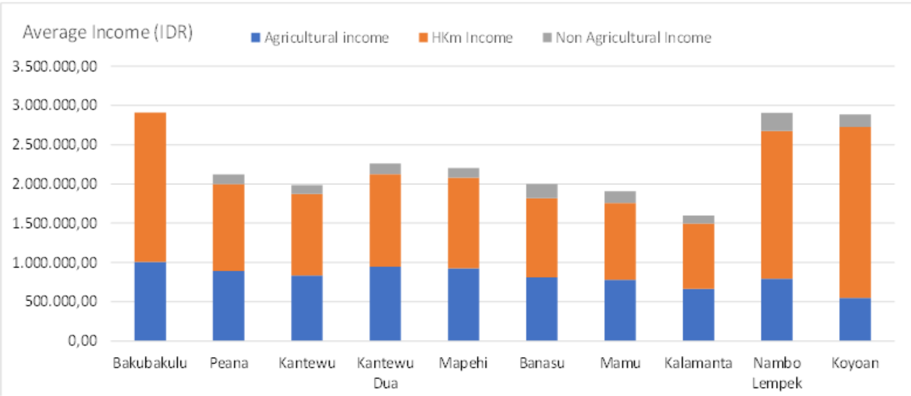
The average income of HD's areas from forest resource utilization was IDR 379.543 to IDR 753.531 per month. (US$1 ≈ 15.410 IDR). This finding confirms that forest resource utilization activities in the HD area have not been implemented optimally. Most of the HD licenses in Central Sulawesi were issued in 2017, except for HD Namo and HD Lonca, which had licenses in 2013 and 2014.

The average contribution of the HKm area in increasing the local community's income was 56,38%. However, this contribution did not originate from the HKm group, but it was obtained from individual community land-use activities based on the market's demand. The forest resource utilization has not yet been implemented based on the management plan. This research reveals that land-use decisions in the HKm area were not a collective decision of the group but rather a personal decision. The



Average HD Income Contribution (9.43)	19.03%	27.31%	16.15%	0.00%	11.33%	0.00%	0.00%	0.00%	0.00%	14.75%	15.19%

Figure 5. Income contribution of HD



HKm Income Contribution (56.38%)	68,26%	52,38%	52,36%	52,22%	52,49%	50,59%	51,19%	52,06%	64,79%	67,44%

Figure 6. Income contribution of HKm

community uses land in the forest area to meet their daily needs.

Farmers' income from forest utilization activities in HKm areas was generally higher than income from agricultural activities outside HKm areas. This condition confirms that, in general, the communities strongly depend on land resources in the HKm area to support their daily needs. The income level of farmers from land use in the HKm area was IDR. 831.323 to IDR. 2.169.000 per month. The average farmer's income from land use in the Hkm area was IDR. 1.326.750 per month (US$1 ≈ 15.410 IDR).

C. The role of stakeholders and exogenous variables in the SF policy

SF's policy outcomes of Central Sulawesi have not been optimal based on several of the criteria i.e; self-governing of local institutions was still in the moderate category, forest resources sustainability has not been achieved, and SF's contribution to the community's income was in a low category. These outcomes were attributed to the weakness in the action situation for the acceleration of SF policy. The SF development action in Central Sulawesi Province was more concentrated on licensing facilitation, even though several stakeholders have assisted in strengthening the capacity of groups in the utilization of forest resources. However, strengthening these groups' capacity was still concentrated in a limited number of locations, and some were also not implemented in a sustainable and integrated manner. The SF program development's action situation has not significantly impacted the community income and preserving forest resources.

Based on the IAD framework (Ostrom, 2011), the internal structure of an action situation consists of actors, positions, and actions. This study adopts the terms the roles of stakeholders, including their interests and capacities. Stakeholders that have played a high role in SF development in Central Sulawesi were the Forestry Service, FMUs, and NGOs. The forestry office's role focuses on the administrative aspect, while FMUs and NGOs' role focuses on mentoring and outreach activities to the community. Unfortunately, FMUs and NGOs have limited funding capacities and personnel to carry out assistance activities to community groups.

The Central Sulawesi provincial government's target of allocating SF of 100.000 ha to improve the community's economy around the forest has the potential to backfire. It could even threaten the sustainability of forest resources if the role of stakeholders in the action situation is not regulated and strengthened. The local government should organize multi-stakeholder roles to strengthen the capacity of the SF group by considering the interests and power of the stakeholders, including the involvement of district local governments. Apart from a structural approach through structuring roles, local government should also expand network governance through a communication approach in multistakeholder dialogue among all stakeholders concerned with SF Development. The role of local government in network governance is to have an equal position with other stakeholders (Meuleman, 2008).

At the site level, facilitators are needed to assist community groups in arranging forest resources planning and capacity building. Strengthening facilitators' capacity should be focused on the program to increase their knowledge and skills in assisting farmer groups to formulate forest utilization activities that support forest sustainability while assuring the improvement of the community's economy. Access to capital and information is also crucial for local communities to benefit from the SF program (Ragandhi et al., 2021). In addition to providing legal access to forest resources, stakeholders also play a role in empowerment actions to facilitate increasing community access to capital, knowledge, and information.

In addition, factors that should be considered in strengthening group capacity are exogenous variables. The potential of forest resources, community dependence on forest resources, and policies or regulations related to SF are exogenous variables that simultaneously determine farmer behavior and SF outcomes. Characteristics of forest resources and community dependence on forest resources are different in each location. In the HKm area, the characteristics of forest resources are quasi-private property, even though it is a state forest area; while in the HD area, it is a communal property managed by the village government. These characteristics have implications for SF outcomes. Therefore, stakeholders who are involved in implementing the SF policy should understand well the exogenous variables that will determine the performance of the SF establishment.

V. CONCLUSION

The outcome of SF policy was affected by the role of stakeholders in the action situation implementing SF policy and exogenous variables. The core of the implementation of the SF policy is community empowerment activities. It requires multi-stakeholder roles from the regional level to the site level. The role of the SF Working Group at the Provincial level only focuses on achieving the broad target. Still, the role of the SF Working Group in the empowerment process has yet to be optimal after the SF approval was issued, which is indicated by the three pillars of the SF goal not having been achieved optimally. The extensive target of the government for the SF acceleration program can be a threat to forest resource sustainability. Furthermore, the SF program will not be able to provide economic benefits for local communities if appropriate community empowerment activities do not support it. The strategy to improve the SF outcomes should begin with arranging the roles of stakeholders and increasing their capacity to support the SF group's empowerment. Stakeholders involved in community empowerment activities at the site level should conceive the exogenous variables. The exogenous variables encompass community dependence on forest resources, market aspects, and forest resource potential are the dominant factors that specify the interaction of forest resource use in the SF area. The problem that needs to be resolved in the HKm scheme is to secure the preservation of forest area functions as a common interest, whereas the HD scheme is strengthening the LPHD capacity to intensify forest management to increase the village's income.

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Appendix

Criteria for assessing self-governing of the local institution in managing SF

Criteria	Score	Description
Active community participation	3	members of the SF group meet regularly and participate by offering comments and feedback.
	2	SF members conducting meetings, but only sometimes
	1	SF members have never met in the last year
Fairness in resource use	3	More than 50% have the same opportunity to utilize forest resources and earn income from HD businesses
	2	Less than 50% of respondents stated that there is fairness in using forest resources because they have equal opportunities
	1	More than 50% of respondents stated that it is unfair to use forest resources.
Community attitudes to the forest	3	No communities are encroaching on forest areas
	2	There are still communities that encroach on forest areas
	1	There are still many communities that encroach on forests
Role of local institutions in planning and regulating forest resource use	3	The SF management has arranged an SF management plan and annual work plan and has received approval
	2	The SF management has arranged an SF management plan and annual work plan but has yet to attain approval.
	1	The SF management has not yet arranged a plan.
Role of local institutions in monitoring forest	3	Monitoring is conducted by SF management a minimum of twice per year.
	2	Monitoring is conducted by SF management less than twice per year.
	1	The SF administration has never performed monitoring.
Role of local institutions in applying local sanctions	3	Local institutions of SF can apply sanctions to those who violate them
	2	Local institutions of SF can only give warnings, but those who violate are handed over to the authorities
	1	Local institutions of SF do not apply sanctions to violators.
Role of local institutions in conflict resolution	3	There is a conflict resolution mechanism, and local institutions can resolve conflicts.
	2	There is a conflict resolution mechanism in SF, but local institutions cannot resolve it.
	1	Local institutions do not handle conflicts within the SF.
Local institutional capacity	3	Local institutions have competence in forest management planning and access to funding and business capital.
	2	Local institutions have competence in forest management planning but do not have access to funding and business capital.
	1	Local institutions do not have competence in forest management planning and access to funding and business capital.

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PREDICTING THE POTENTIAL DISTRIBUTION OF *Pinus cernua* L.K. PHAN EX AVER., K.S. NGUYEN AND T.H. NGUYEN, A CRITICALLY ENDANGERED CONIFER SPECIES

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PREDICTING THE POTENTIAL DISTRIBUTION OF *Pinus cernua* L.K. PHAN EX AVER., K.S. NGUYEN AND T.H. NGUYEN, A CRITICALLY ENDANGERED CONIFER SPECIES. *Pinus cernua* L.K. Phan ex Aver., K.S. Nguyen and T.H. Nguyen (Pinaceae) is a critically endangered species restricted to the Laos - Vietnam border. The population of this species has been declining due to habitat loss and forest fire. Predicting the potential distribution of the species is an important priority for conservation plans and strategies. In this study, a MaxEnt model was used for predicting the potential distribution of *P. cernua* using 21 occurrence data and 13 environmental variables. Precipitation of driest month (with 32.3% of contribution), annual mean diurnal range (23.4%), elevation (18.4%), and aspect (12.3%) are crucial factors for predicting the species' potential distribution in the MaxEnt model, while remaining factors are less important factors. The suitable distribution was predicted in the north-western region of Vietnam and the adjacent regions of Son La and Thanh Hoa provinces (Vietnam) and Houaphan province (Laos) with 1,544 km^2 in total. The high, medium, and low suitability areas are 159 km^2 (10%), 475 km^2 (31%), and 910 km^2 (59%), respectively. The current protected areas do not contain many of the possible habitats for this species. Priority should be given to conservation efforts for species in these potentially suitable locations both in- and outside of current protected areas, particularly in the surrounding area of Vietnam and Laos.

Keywords: Conservation, conifer, critically endangered species, ecological niche model, geographic distribution

MEMPREDIKSI DISTRIBUSI POTENSIAL Pinus cernua *L.K. PHAN EX AVER., K.S. NGUYEN DAN T.H. NGUYEN, SPESIES KONIFER YANG TERANCAM PUNAH SECARA KRITIS.* Pinus cernua *L.K. Phan ex Aver., K.S. Nguyen dan T.H. Nguyen (Pinaceae) adalah spesies yang terancam punah secara kritis dan terbatas di perbatasan Laos - Vietnam. Populasi spesies ini telah menurun akibat hilangnya habitat dan kebakaran hutan. Memprediksi distribusi potensial spesies ini adalah prioritas penting untuk rencana dan strategi konservasi. Dalam penelitian ini, model MaxEnt digunakan untuk memprediksi distribusi potensial* P. cernua *menggunakan 21 data kemunculan dan 13 variabel lingkungan. Curah hujan pada bulan terkering (dengan kontribusi 32,3%), rata-rata tahunan kisaran diurnal (23,4%), elevasi (18,4%), dan aspek (12,3%) adalah faktor penting untuk memprediksi distribusi potensial spesies dalam model MaxEnt, sedangkan faktor lainnya kurang penting. Distribusi yang cocok diprediksi di wilayah barat laut Vietnam dan daerah sekitar provinsi Son La dan Thanh Hoa (Vietnam) dan provinsi Houaphan (Laos) dengan total 1.544 km^2. Daerah dengan kesesuaian tinggi, sedang, dan rendah masing-masing adalah 159 km^2 (10%), 475 km^2 (31%), dan 910 km^2 (59%). Area yang dilindungi saat ini tidak mencakup banyak habitat yang mungkin untuk spesies ini. Prioritas harus diberikan kepada upaya konservasi untuk spesies di lokasi yang berpotensi sesuai ini baik di dalam maupun di luar area yang dilindungi saat ini, khususnya di daerah sekitar Vietnam dan Laos.*

Kata kunci: Konservasi, konifer, spesies yang terancam punah secara kritis, model relung ekologi, distribusi geografis

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I. INTRODUCTION

Globally, a large number of species (approximately 20 percent) are on the verge of extinction (Brummitt & Bachman, 2010; Brummitt et al., 2012) due to habitat degradation and fragmentation, alien species invasion, overexploitation, increasing human population, and climate change (Barnosky et al., 2011; Haddad et al., 2015; Nogué et al., 2009). The rare, endemic species distributed in fragmented and narrow (and single) geographical areas (Işik, 2011; Jump & Penuelas, 2005; Primack, 2006) are prone to environmental changes. Gymnosperms (i.e., conifers, cycads) are the most threatened group (Brummitt & Bachman, 2010; Brummitt et al., 2012), with about 40 percent of the conifer species at risk of extinction, especially in the Asia region (Forest et al., 2018; IUCN, 2023a; Magri et al., 2020; Rosenblad et al., 2019). Therefore, endemic species (i.e., conifers) are important targets for conservation and management (Myers et al., 2000; Rosenblad et al., 2019).

To conserve endemic and threatened species, detailed knowledge on the range of their potential distribution is necessary. However, incomplete information on the distribution of endemic and threatened species has caused many difficulties in conservation and management activities (Gogol-Prokurat, 2011; Mousikos et al., 2021). Species distribution modeling (or ecological niche modeling) has been an effective approach to determine the current potential distribution areas and identify the environmental requirements of species (Guisan et al., 2002; Giriraj et al., 2008; Gogol-Prokurat, 2011), project the species distribution in the past, and assess the influence of climate change on species distribution (Dai et al., 2022; Qin et al., 2017), which may help managers and conservationists save time and budget to inform conservation planning and decisions. Among species distribution models, Maximum Entropy (MaxEnt) is considered to be a popular model for estimating the potential distribution areas of species, especially endemic and threatened species, because it has some advantages: 1) It requires only species occurrence (even small size) data and environmental information as input data; 2) Both continuous and categorical data are simultaneously handled; and 3) It tests model robustness using cross-validation, bootstrapping, and repeated subsampling in replicated runs. (Phillips, Anderson, & Schapire, 2006; Phillips & Dudík, 2008; Elith et al., 2011; Garcia et al., 2013; Wang et al., 2015). *Pinus cernua* L.K. Phan ex Aver., K.S. Nguyen and T.H. Nguyen has been listed as Critically Endangered (CR) in the International Union for Conservation of Nature Red List (IUCN, 2023b), distributed on very steep slopes and cliffs at approximately 900 – 1,800 m a.s.l.,on the transboundary range between Son La (Vietnam) and Houaphan (Laos) provinces (Averyanov et al., 2014; Averyanov et al., 2015; Averyanov et al., 2017; Loc et al., 2017). The population of the species is small, with more than 250 mature individuals, but the population has declined significantly due to deforestation and loss of habitat related to wildfire and human activities (i.e. illegal logging) (Averyanov et al., 2015; Averyanov et al., 2017; IUCN, 2023b).

In recent years, studies have focused on seed germination, seedling cultivation, and biological characteristics of *P. cernua* (Averyanov et al., 2015; Hoa et al., 2016; Loc et al., 2017). However, the information may not be adequate to build a scientific conservation plan for the species. Thus, a comprehensive study on the potential distribution and environmental requirements of *P. cernua* is essential for conservation aspects.

In this study, we predicted the possible habitat range of *P. cernua* using data of its presence in northern Vietnam and Laos, and utilized Maxent modeling to identify the important environmental factors affecting P. cernua distribution. The results of this investigation could help with planning for the species' conservation.

II. MATERIALS AND METHODS

A. Species occurrence data

Twenty-one location points of *P. cernua* were obtained from previous published literatures, including Averyanov et al. (2014), Averyanov et al. (2015), Hoa et al. (2016), and Loc et al. (2017), used in this study. (Figure 1).

B. Environmental variables

Twenty-four variables were selected and used as predictors in models (Table 1). In particular, 19 bioclimatic variables from 1970 to 2000 were obtained from the WorldClim website http://www.worldclim.org/ (Fick & Hijmans, 2017) at 1 km resolution. The elevation variable with the resolution of approx. 90m was extracted from the Global Digital Elevation Map (GDEM) generated from the CGIAR Consortium for Spatial Information (https://srtm.csi.cgiar.org) (Jarvis, Reuter, Nelson, & Guevara, 2008). Slope and aspect layers were extracted from the elevation layer using the Surface Analysis tool in ArcGIS version 10.1 (ESRI, 2015).

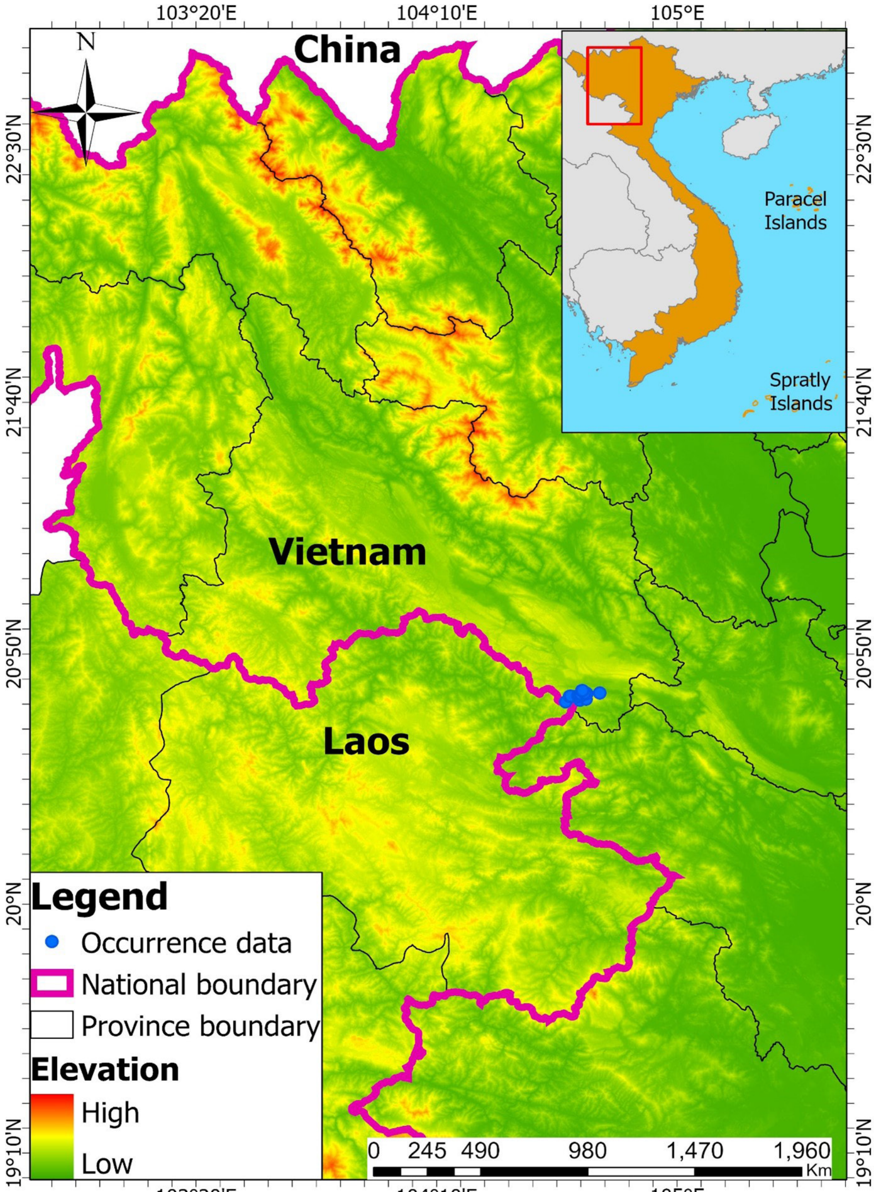

Figure 1. The research site

Table 1. Environmental variables used in this study

Variable	Unit	Code
Annual mean temperature	ºC	bio_01
Annual mean diurnal range (Mean of monthly =max temp - min temp)	ºC	bio_02*
Isothermality (BIO2/BIO7) (* 100)	-	bio_03
Temperature seasonality (standard deviation *100)	C of V	bio_04*
Max temperature of warmest month	ºC	bio_05
Min temperature of coldest month	ºC	bio_06*
Annual temperature range (BIO5-BIO6)	ºC	bio_07*
Mean temperature of wettest quarter	ºC	bio_08
Mean temperature of driest quarter	ºC	bio_09
Mean temperature of warmest Quarter	ºC	bio_10
Mean temperature of coldest quarter	ºC	bio_11
Annual precipitation	mm	bio_12*
Precipitation of Wettest month	mm	bio_13
Precipitation of driest month	mm	bio_14*
Precipitation seasonality (Coefficient of variation)	mm	bio_15*
Precipitation of wettest quarter	mm	bio_16
Precipitation of driest quarter	mm	bio_17
Precipitation of warmest quarter	mm	bio_18*
Precipitation of coldest quarter	mm	bio_19
Land cover	type	lulc*
Soil organic carbon (0-30cm in depth)	t/ha	soc*
Elevation	m	elevation*
Slope	degree	slope*
Aspect	degree	aspect*

Note: * indicated that these variables were used in modeling.

Soil organic carbon (SOC) with a spatial resolution of 1 km was obtained from the Global Soil Organic Carbon Map (GSOCmap, version 1.5). The index is available and provided by FAO and ITPS (2018). Land cover layers at 10 m resolution in 2020 were collected from the website https://env1.arcgis.com/arcgis/rest/services/Sentinel2_10m_LandCover/ImageServer (Karra, 2023).

All the spatial layers of variables used in MaxEnt models were resampled to 90 m using the Resample tool in ArcGIS 10.1 (ESRI, 2015). In order to avoid the influence of multicollinearity, we used ENMTools (version 1.4.4, Warren et al. (2010)) to determine the correlation among variables. We did not include variables with a high correlation (>|0.8|) in the same model (Table A1). As a result, 13 variables were eventually chosen to model the distribution of *P. cernua* (Table 1).

C. Species distribution modeling

The Maximum Entropy Model (MaxEnt) (version 3.4.4; Phillips et al., 2023) was used for predicting the potential distribution of *P. cernua*. The ENMval package in R (version 3.6.3, Muscarella et al. (2014)) was used to choose the best model to predict species' potential distribution based on the AICc value. The minimum AICc value indicates the best model (Muscarella et al., 2014). Ultimately, the model with the feature class H (hinge) and a regularization value of 3 was selected; thus, the setting was chosen for the final models. The species occurrence datasets in Section 2.1 were repeated for 21 replicates (Pearson et al., 2007). Maximum iterations were 5,000.

The area under the curve (AUC) was used to determine the accuracy of the model. The AUC value ranges from 0 (low accuracy) to 1 (high accuracy) (Fielding & Bell, 1997; Phillips et al., 2006). The Jacknife method was used to assess the importance of variables for predicting the potential distribution of *P. cernua* in the MaxEnt model.

The response curves from MaxEnt's result show the relationship between species' potential distribution and environmental factors.

Finally, a map layer was generated by the MaxEnt model, representing suitability levels (from 0 (not suitable) to 1 (highly suitable). The "10th percentile training presence logistic threshold" was used as a threshold to identify the suitable for the species, according to the suggestion of Liu et al. (2005). Four levels were categorized, including: unsuitable habitat (<0.736), low suitable habitat (0.736-0.816), medium suitable habitat (0.816-0.896), and high suitable habitat (>0.896).

III. RESULTS AND DISCUSSION

A. Result

The MaxEnt model (AUC = 0.99) has better performance than the random model (AUC = 0.5) (Figure 2). Our model indicated that climate group was identified as the main factor contributing to the potential distribution of this species with 61.7% of cumulative contribution, especially precipitation of the driest month (32.3%) and mean diurnal range (23.4%), followed by topography (e.g., elevation (18.4%), aspect (12.3%) (30.7%). Soil organic carbon (soc) and land cover (lulc) were less contributing with 6.8% and 0.8%, respectively (Table 2).

The response curves of four main variables and others to *P. cernua* habitat suitability are shown in Figure 3. According to the obtained response curves of the species, *P. cernua* prefers habitats at 1,000 – 1,500 m elevation and in the North and North-east areas with precipitation of driest month less than 8 mm and an annual mean diurnal range around 7.5º. Additionally, the response curves of nine remaining environmental variables, shown in Figure A1, indicated that the potential distribution of this species occurred in the areas where temperature seasonality ranged 3.5 – 4ºC, the minimum temperature of the coldest month was around 8ºC, and the annual temperature range was less than 18ºC. The suitable annual precipitation, precipitation seasonality, and precipitation of the warmest quarter were approximately 1,400 mm, 91 mm, and 700 mm, respectively. In terms of land cover, this species preferred clustering of tall dense vegetation with a closed canopy. Suitable soil organic carbon less than 50 tones/ha.

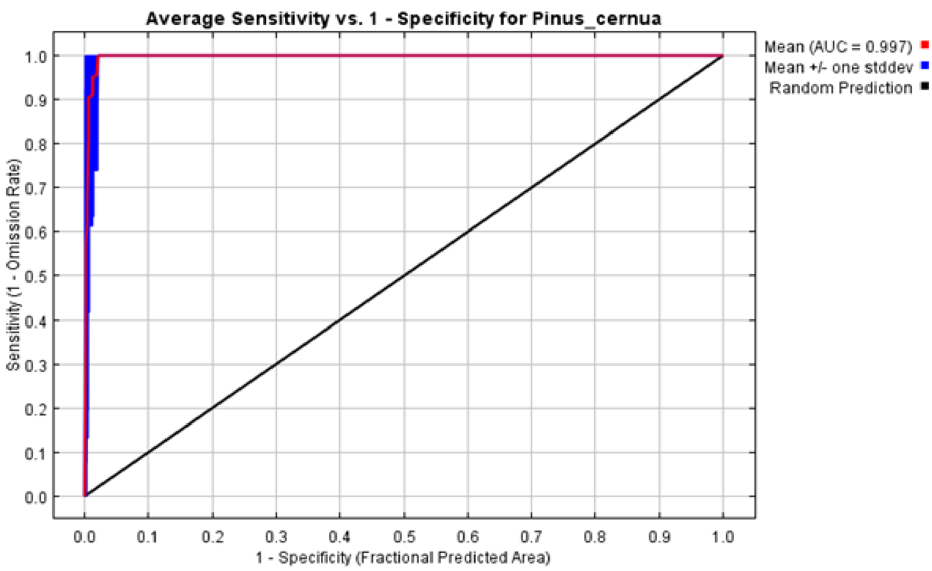

Figure 2. The AUC value and ROC curve of the Maxent model for *P. cernua*

Table 2. The percentage contribution of environmental variables used in the MaxEnt model for predicting the potential distribution of *P. cernua*

Variable	**Code**	**Percent contribution**
Precipitation of driest month	bio_14	32.3
Annual mean diurnal range (Mean of monthly =max temp - min temp)	bio_02	23.4
Elevation	elevation	18.4
Aspect	aspect	12.3
Soil organic carbon	soc	6.8
Temperature seasonality (standard deviation *100)	bio_04	5.0
Land cover	lulc	0.8
Annual temperature range (BIO5-BIO6)	bio_07	0.8
Annual precipitation	bio_12	0.2
Min temperature of coldest month	bio_06	0
Precipitation of warmest quarter	bio_18	0
Slope	slope	0
Precipitation seasonality (Coefficient of Variation)	bio_15	0

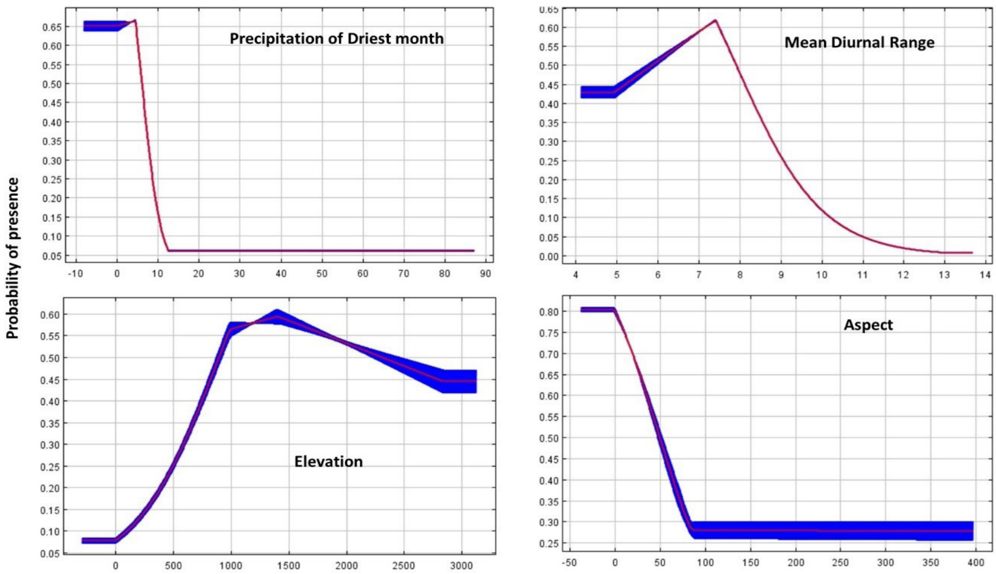

Figure 3. *P. cernua* response curves in relation to the four most important environmental variables

Jackknife test results showed that climatic variables demonstrated the highest gain in AUC, indicating their crucial contribution to the distribution of *P. cernua*, followed by topography (i.e., elevation and aspect) and soil organic carbon. Whereas land cover and slope had the lowest gain in AUC, showing a minimal effect on prediction of species distribution (Figure 4). The results of the Maxent indicated that the effect of climatic factors on the distribution of *P. cernua* is greater than that of other factors.

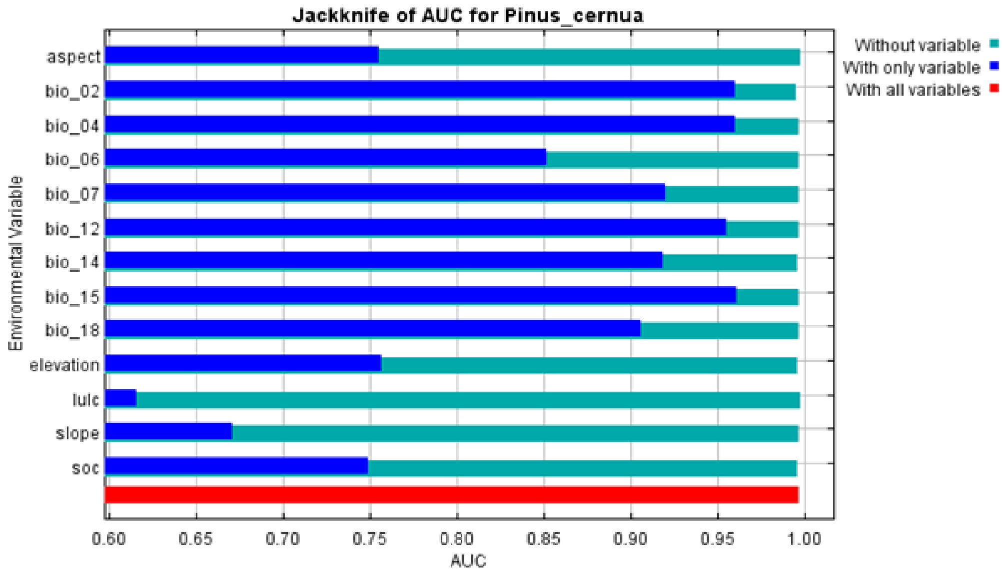

Figure 4. The relative importance of environmental variables based on the jackknife test of area under the curve (AUC). The abbreviations of variables were detailed in Table 1

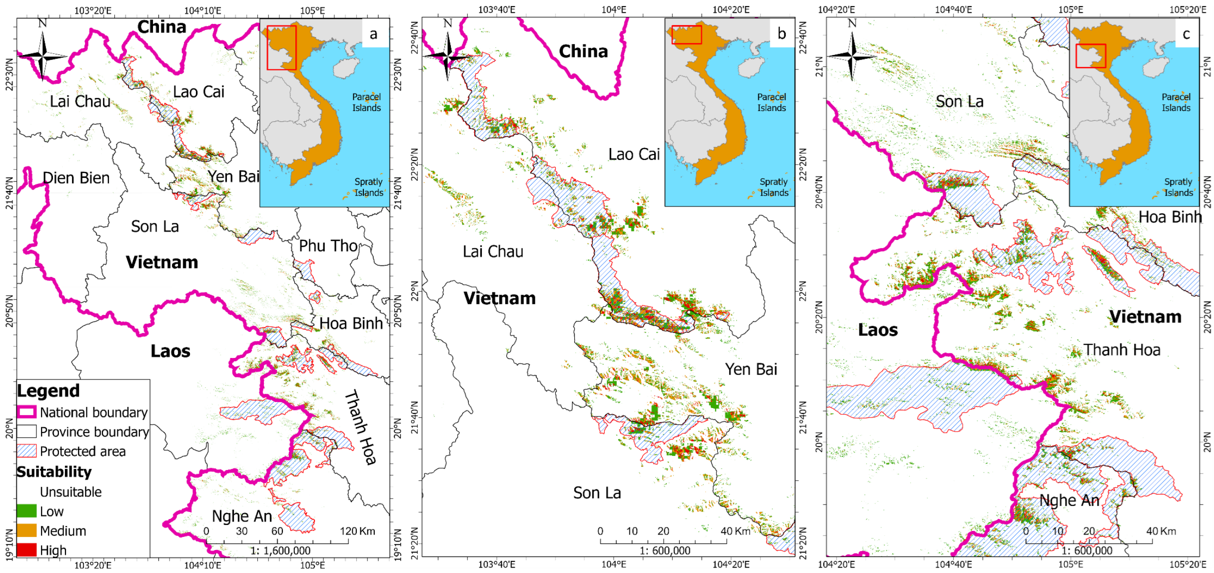

Figure 5. Current potential suitable habitat of *P. cernua* in Northern, Vietnam
Notes:(a: the whole studied area; b: the north of the studied area; c: the south of the studied area). The protected areas were downloaded from http://www.protectedplanet.vn/en.

Figures 5 and 6 show the potential distribution map of *P. cernua*. The total predicted suitable habitat area of the species was approximately 1,544 km^2, ranges c. 19ºN – 23ºN and 103ºE – 106º30'E, mainly distributed in north-western and north-central Vietnam (Son La, Hoa Binh, Lao Cai, Lai Chau, Phu Tho, Yen Bai, Thanh Hoa, and Nghe An provinces) and Houaphan province (Laos). The high, medium, and low suitable habitat areas are 159 km^2 (10%), 475 km^2 (31%), and 910 km2 (59%), respectively. In the high suitable areas, Thanh Hoa, Lao Cai, Son La, and Yen Bai provinces (Vietnam) occupy the largest areas at 46 km^2, 44 km^2, 24 km^2, and 22 km^2, respectively, followed by smaller areas in Nghe

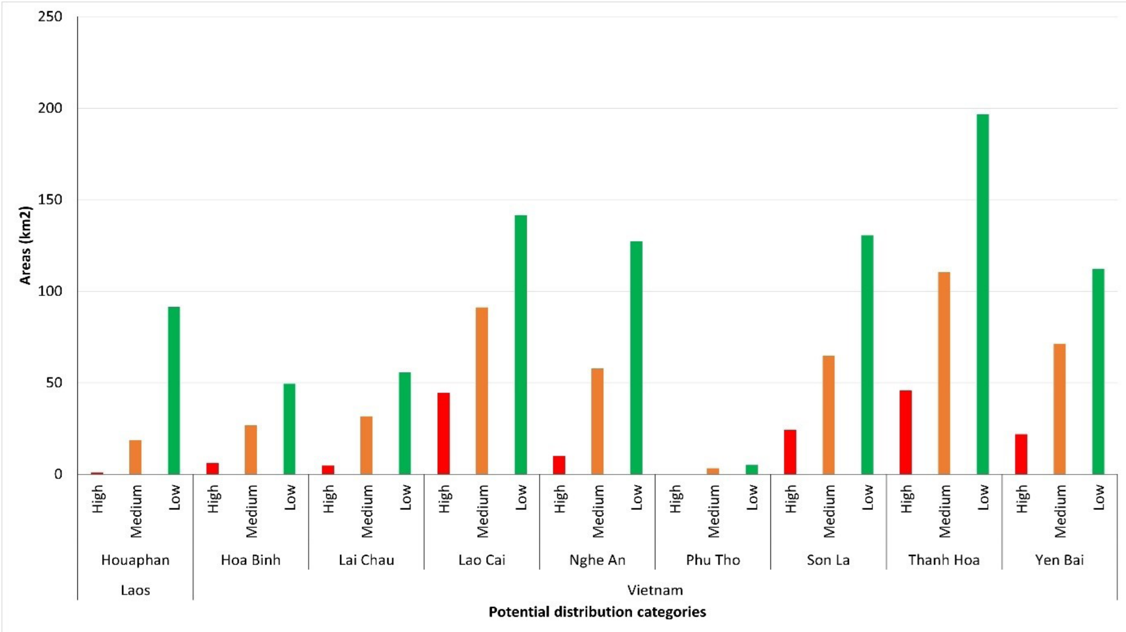

Figure 6. Areas for the low, medium, and high potential distribution of *P. cernua* in Houaphan (Laos), Yen Bai, Thanh Hoa, Nghe An, Hoa Binh, Lai Chau, Lao Cai, Phu Tho, and Son La, (Vietnam) provinces

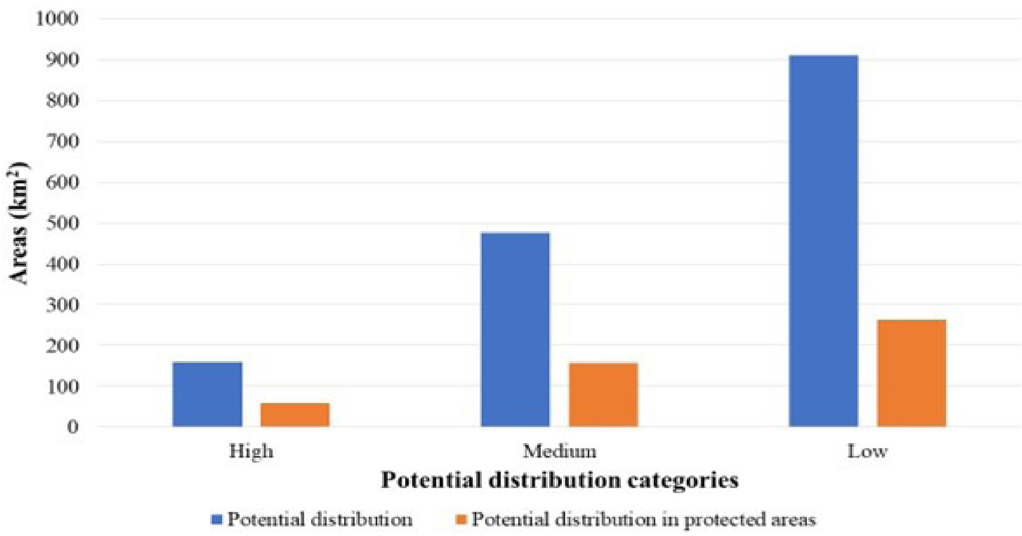

Figure 7. Areas for the low, medium, and high potential distribution of *P. cernua* in total and in protected areas

An, Hoa Binh, Lai Chau, Phu Tho (Vietnam), and Huoaphan (Laos) provinces. Total of predicted suitable habitat of this species within protected areas is 479 km^2 (~ 31% of the total predicting potential suitable areas from model) (Figure 7).

B. Discussion

Spatial distribution of species is linked to environmental conditions due to long term species – environment interactions (Jiang et al., 2014; Kaeslin et al., 2012; Wisz et al., 2013). Temperature and precipitation are important factors influencing the growth and spread of plant species (Cornett et al., 2000; García et al., 2000; Ruan et al., 2012; Wiens et al., 2010; Xie et al., 2022). The MaxEnt model shows that climatic factors are the most important for predicting the potential distribution of *P. cernua* in the studied area. From the results of the MaxEnt model, the suitable annual mean diurnal range was around 7.5°C, precipitation of the driest month was less than 8 mm, and annual precipitation ranged 1,000 – 1,500 mm (Figure 3 and A1), which is in accordance with these climatic characteristics in the study area obtained from the local meteorological station (Quynh, 2024), including the annual mean diurnal range (7.8°C), precipitation of the driest month (10 mm) and annual precipitation (1,500 mm). Also, the results agree with Averyanov et al. (2017) who reported that *P. cernua* occupies areas with an average annual precipitation above 1,000 mm. Therefore, the suitable habitats of *P. cernua* may prefer humid areas at high elevation with low temperatures that strongly affect buds for mountainous gymnosperms (Pan et al., 2022). The effect of climatic factors on *P. cernua* distribution range is consistent with factors influencing the suitable habitats of some high mountain coniferous species such as *Cephalotaxus oliveri* (Xie et al., 2022) and *Thuja sutchuenenis* (Qin et al., 2017), indicating that climatic factors were the key drivers in these species' distribution. In Vietnam, Tuyet and Tra (2021) showed that climatic factors had crucial effects on the spatial distribution of *Cupressus torulosa*. The importance of climatic factors in the Maxent model for predicting the species' potential distribution may indicate that climate change will affect its distribution in the future. Moreover, topography in mountain areas in northern Vietnam is complex (Averyanov et al., 2003), which is considered a major factor influencing local climate (Meehl, 1992; Ogwang et al., 2014) and results in strong microclimate heterogeneity (Opedal et al., 2015). Thus, in further in-depth studies on *P. cernua* conservation, attention should be given to microclimate at a fine scale and the effect of climate change on this species distribution.

Topography (i.e., elevation, aspect) is also an important variable for species distribution. Topography is considered an influencing factor of climate and soil condition, which contribute to species distribution (Barry, 2008; Bunyan et al., 2015; Grzyl et al., 2014; Jiao et al., 2009; Youcefi et al., 2020). The results of the MaxEnt model indicate that the suitable distribution areas (especially high suitability) are concentrated on the north, north-west, and north-east aspects at high elevations (1,000 – 1,500 m) in tropical forests in the north-western region of Vietnam and the eastern areas of Houaphan provinces (Laos), which have many peaks higher than 1000 m, such as Hoang Lien Son (3,143 m), Pa Phanh (1,400 m), Pha Luong (1,500 m), and Ta Sua (2,400 m), indicating this species might respond sensitively to temperature and precipitation as noted above. The result is in accordance with the known distribution range recorded by Averyanov et al. (2014), Averyanov et al. (2017), and Loc et al. (2017), who reported that this species occurred on the north, north-west, and north-east at 900 – 1,800 m elevation, which receive lower solar radiation, heavy rainfall, and have higher tree cover compared to other aspects.

Unlike the above factors, land cover is less important for the model. The result of the model shows that *P. cernua* tends to distribute in areas characterized by tall, dense vegetation (Figure A1). The result agrees with Averyanov et al. (2017), who reported that *P. cernua* mainly occurred in primary evergreen coniferous tropical submontane forest and primary evergreen mixed tropical submontane forest, which are main land cover types at elevations above 1,000 m a.s.l. in the studied area. However, a part of these land cover types is replaced by secondary forest, pastures, and agricultural fields.

The areas of potential distribution for the *P. cernua* from MaxEnt modeling are consistent with the known distribution reported in many previous studies (Averyanov et al., 2015; Averyanov et al., 2017; Hoa et al., 2016; Loc et al., 2017; Thomas, 2022), and suggest that the distribution areas of this species represent its optimum climate in wet, cool, and/or cold sites at high elevation. Additionally, the potential suitable habitats for the *P. cernua* species occupy not only in the forest areas with a high elevation and characterized by the montane climate in Son La (Vietnam) and Houaphan (Laos) provinces (reported by Averyanov et al. (2017)), but also in other forest places with similar elevation and climate conditions in the north-western region of Vietnam (e.g. Lai Chau, Lao Cai, Phu Tho, Yen Bai, Thanh Hoa, and Hoa Binh provinces) and the adjacent areas of Son La and Thanh Hoa provinces (Vietnam) and Houaphan province (Laos) (mainly in Pha Luong and Pa Phanh mountain ranges), where the species has not been recorded so far. These results agree with previous studies (Kumar & Stohlgren, 2009; Pearson, 2007; Yang et al., 2013) that found that the Maxent model using only presence data often overestimates the potential distribution areas compared to the observed niche of species.

From the results of models, most suitable areas lie outside of existing protected areas, which may cause adverse influences on the species population in the future by human activities (i.e., illegal logging, fire). It is important that new protected areas should be established for conservation of this species and its habitat, but the establishment of protected areas must depend on the overall and long-term national planning. Thus, conservation outside the protected areas is crucial for this species, as noted below. The potential distribution areas of this species lie in the adjacent areas between Son La, Thanh Hoa (Vietnam), and Houaphan (Laos) provinces. Thus, effective cross-border conservation partnerships should be a key component to successful management of this transboundary critically endangered species. For instance, managers should disseminate local people about the species conservation practices. In addition, inventories should be conducted to explore the new locations, especially high-suitable areas where *P. cernua* may already exist, as well as protect and maintain its habitat and mature individuals. In terms of ex-situ conservation, seeding and cutting propagation should be used to provide seedlings for conservation planting and reintroduction programs in (highly) suitable areas because natural regeneration of *P. cernua* is poor (Averyanov et al., 2017). Indeed, seeding and cutting propagation and an experimental model for the species ex-situ conservation were conducted by managers and scientists and have been successful in Son La province (Averyanov et al., 2015; Hoa et al., 2016). The successful model may be applied in other suitable areas to conserve this species and avoid extinction in the future.

V. CONCLUSION

The MaxEnt model results indicate that the suitable areas for *P. cernua* are approximately 1,544 km^2 in the north-western of Vietnam and on the Laos-Vietnamese border between Son La, Thanh Hoa (Vietnam), and Houaphan (Laos) provinces. The contribution of precipitation of the driest month in the MaxEnt model to predict the species' potential distribution is highest, followed by annual mean diurnal range and elevation. Most suitable habitats of *P. cernua* are not found within existing protected areas. This study may provide a better understanding of environmental factors influencing the species' potential distribution in northern Vietnam and provide recommendations for evidence-based transboundary conservation management in the distribution ranges of the endemic and threatened tree species.

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GROWTH AND WOOD TRAITS EVALUATION OF 15-YEAR-OLD TENGKAWANG (*Shorea* spp.) TREE STANDS IN GUNUNG WALAT UNIVERSITY FOREST, WEST JAVA, INDONESIA

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GROWTH AND WOOD TRAITS EVALUATION OF 15-YEAR-OLD TENGKAWANG (SHOREA SPP.) TREE STANDS IN GUNUNG WALAT UNIVERSITY FOREST, WEST JAVA, INDONESIA. Gunung Walat University Forest (GWUF) in Sukabumi Regency, Indonesia, plays a crucial role in providing various ecosystem services. Five important *Shorea* trees, i.e., *Shorea stenoptera, S. mecisopteryx, S. pinanga*, *S. palembanica*, and *S. leprosula* have been planted in GWUF as an effort for its conservation and object of research. An evaluation of the adaptability and suitability of these species to the GWUF ecosystem, as well as their wood characteristics, needs to be carried out regularly. Therefore, the study aimed to examine the growth performances and physical wood properties of five *Shorea* species, i.e., *Shorea stenoptera*, *S. mecisopteryx, S. pinanga*, *S. palembanica,* and *S. leprosula* at the age of 15-year-old planted in GWUF. The results indicated that *S. leprosula* exhibited the best growth performance in terms of average diameter (19.64 cm), volume (0.27 m^3), slenderness (126.58), and wood density (0.94 g/cm^3), and *S. stenoptera* showed the best performance in average height (23.35 m). While the poor performance was shown by *S. palembanica* in terms of average diameter (6.73 cm), height (11.15 m), volume (0.02 m^3), wood density (0.87 g/cm^3), and specific gravity (0.45), and *S. stenoptera* in terms of average slenderness (202.73). In addition, significant differences in tree height, diameter, volume, wood density, specific gravity, and moisture content were found in *S. palembanica* compared with other species. The relationship between the growth and physical wood properties parameters varied between species. The study revealed that planting the five *Shorea* species in GWUF is suitable for increasing vegetation cover and conserving the species.

Keywords: Dipterocarps, ex-situ conservation, education forest, non-timber forest products (NTFPs), *Shorea* spp.

EVALUASI PERTUMBUHAN DAN KARAKTER KAYU TEGKAWANG (SHOREA SPP.) UMUR 15 TAHUN DI HUTAN PENDIDIKAN GUNUNG WALAT, JAWA BARAT, INDONESIA. Hutan Pendidikan Gunung Walat (HPGW) di Kabupaten Sukabumi, Indonesia berperan penting dalam menyediakan berbagai jasa ekosistem. Lima pohon Shorea penting, yaitu Shorea stenoptera, S. mecisopteryx, S. pinanga, S. palembanica, dan S. leprosula ditanam di HPGW sebagai upaya konservasi dan objek penelitian. Evaluasi kemampuan beradaptasi dan kesesuaian dari spesies ini pada ekosistem HPGW serta karakteristik kayunya perlu dilakukan secara berkala. Oleh karena

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itu, tujuan dari penelitian ini adalah untuk menguji performa pertumbuhan dan sifat fisik kayu dari lima jenis pohon Shorea *yaitu* Shorea stenoptera, S. mecisopteryx, S. pinanga, S. palembanica, *dan* S. leprosula *berumur 15 tahun yang ditanam di HPGW. Hasil penelitian menunjukkan bahwa pertumbuhan terbaik ditunjukkan oleh* S. leprosula *dengan rata-rata diameter (19.64 cm), volume (0.27 m^3), kelangsingan (126.58), dan kerapatan kayu (0.94 g/cm^3), dan* S. stenoptera *pada tinggi rata-rata (23.35 m). Sedangkan performa yang buruk ditunjukkan oleh* S. palembanica *dengan rata-rata diameter (6.73 cm), tinggi (11.15 m), volume (0.02 m^3), kerapatan kayu (0.87 g/cm^3), dan berat jenis (0.45), dan* S. stenoptera *pada kelangsingan rata-rata (202.73). Selain itu, perbedaan yang signifikan pada tinggi pohon, diameter, volume, kerapatan kayu, berat jenis, dan kadar air ditemukan di* S. palembanica *dibandingkan dengan spesies lainnya. Hubungan antara parameter pertumbuhan dan sifat fisik kayu bervariasi antar spesies. Hasil penelitian mengungkapkan bahwa penanaman lima jenis pohon* Shorea *di HPGW sesuai untuk meningkatkan tutupan vegetasi dan melestarikan jenisnya..*

Kata kunci: Dipterokarpa, konservasi ex-situ, hutan pendidikan, Hasil Hutan Bukan Kayu (HHBK), Shorea *spp*

I. INTRODUCTION

An educational forest is a forest allocated for education and research activities conducted by students, academics, and researchers to study all aspects related to forestry and the interrelationships among the components of its ecosystem (Wahyudi et al., 2014). Gunung Walat University Forest (GWUF) is one of the educational forests in West Java Province, Indonesia. It was established in 1951 and is currently managed by the Faculty of Forestry and Environment, IPB University. The GWUF is assigned as a forest model that applies the concept of Sustainable Small Scale Forest Management (SSSFM) by relying on non-timber forest products and environmental services (Yahya et al., 2015). This forest has been used as a research location covering almost all physical, biological, social, economic, and environmental aspects by students and researchers from IPB University and other universities (Yahya et al., 2015). As a dense-complex man-made forest ecosystem, GWUF provides various ecosystem services, including provisioning services (e.g. resin from pine and agathis trees, food and feed, energy sources such as firewood and wood pellet, medicinal plants, poisonous plants, and wildlife), regulating services (hydrological, erosion, and flood control functions, air and climate regulating functions, pest and disease prevention, and windbreaker functions), cultural services (ritual site), and supporting services (habitat for various organisms and farming) (Yahya et al., 2015).

Nowadays, GWUF also enhances its supporting services by conserving vulnerable and important Indonesian tree species such as red meranti (*Shorea* spp.) from the Dipterocarpaceae family, which produce not only timber but also non-timber forest products from their fruit known as tengkawang or illipe nut or Borneo tallow nut. The fruit can be used as raw material for vegetable fat, which has a higher value compared to other vegetable oils (e.g., coconut oil) (Winarni et al., 2004; Leksono & Hakim, 2018; Ramadhani et al., 2021). Tengkawang fat quality hinges on several critical physicochemical parameters such as fatty acid, acid number (AN), peroxide number (PN), iodine number (IN), saponification number, and melting point (Abd-Aziz et al., 2023). Tengkawang fat is a blend of triglycerides, consisting of glycerol esters and several unsaturated fatty acids, ranging from 50% to 70% (Ketaren, 2008). The composition of fatty acids in tengkawang fat is mainly made up of stearic acid, oleic acid, and palmitic acid. The percentages for these acids range from 40-46%, 30-32%, and 16-24%, respectively (Darmawan et al., 2020; Abd-Aziz et al., 2023). This makes tengkawang fat a valuable component of cocoa butter equivalent (CBE) blends and allows it to be used directly without further processing (Abd-Aziz et al., 2023). This is also supported by the high melting point of this fat, which is between 34-39^{o}C (Winarni et al., 2004; Leksono & Hakim, 2018; Ramadhani et al., 2021; Abd-Aziz et al., 2023). The properties of tengkawang fat are similar to cocoa butter (Leksono & Hakim, 2018), so the fat can be a substitute for cacao butter in the chocolate industry, margarine, vegetable fat raw material, and cosmetic products such as soap and lipstick (Blicher-Mathiesen, 1994; Lipp & Anklam, 1998; Winarni et al., 2004; Leksono & Hakim, 2018), which are exported to Japan and Europe (Purwaningsih, 2004; Winarni et al., 2017). Tengkawang oil can also be used as a rice seasoning by local people, as a preservative for wet noodles, and in the pharmaceutical industry (Winarni et al., 2004; Setiadi, 2019).

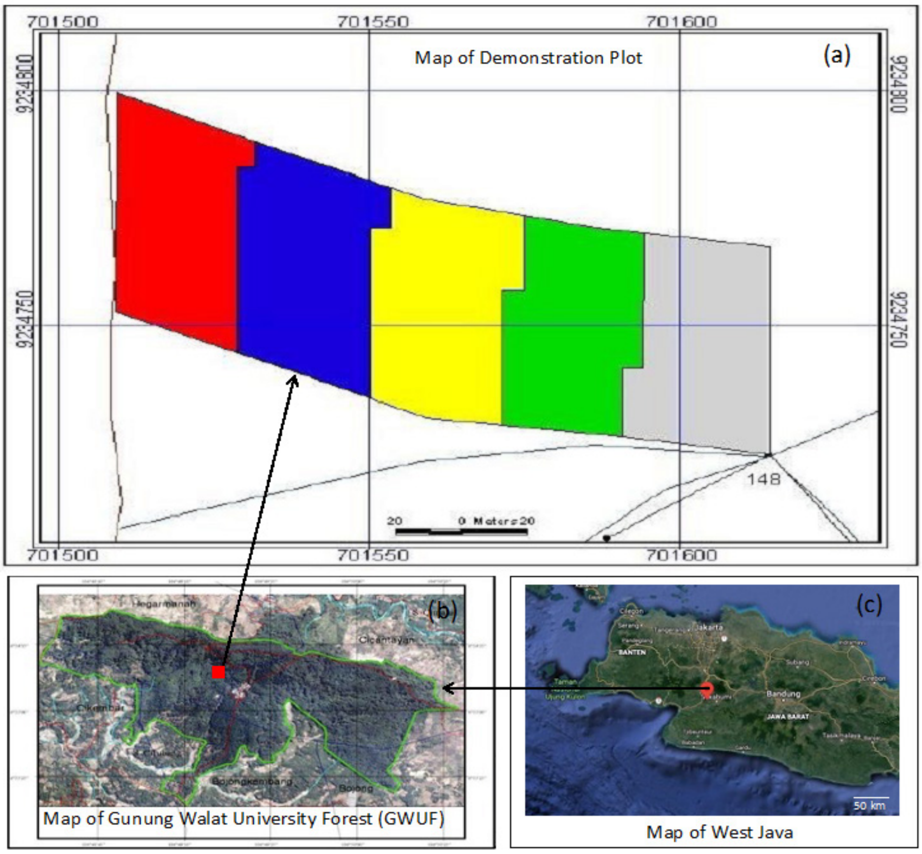
Tengkawang-producing species have a wide natural distribution in Asia, including Indonesia, Malaysia, Sarawak, Sabah, Thailand, the Philippines, and India (Kettle, 2010; Saner et al., 2012; Widiyatno et al., 2014; Winarni et al., 2017) with natural distribution in Indonesia covering Kalimantan and a small part of Sumatera islands (Purwaningsih, 2004; Winarni et al., 2017; Kettle, 2010). Indonesia has about 13 species of tengkawang-producing trees, of which 10 species are found in Kalimantan and 3 other species in Sumatera (Supartini & Fajri, 2014; Leksono & Hakim, 2018). The existence of tengkawang-producing trees in natural forests is decreasing due to increasing illegal logging and timber exploitation activities that do not consider the sustainability aspect (Leksono & Hakim, 2018; Winarni et al., 2017). Besides that, the overexploitation of tengkawang fruits from natural forests and an irregular fruit season hinder natural regeneration (Leksono & Hakim, 2018). In West Kalimantan, for example, a massive harvest season for large fruit tengkawang species occurs once every 3-4 years during the fruit seasons (Bunyamin et al., 2020; Heri et al., 2020). Therefore, several species are currently classified as critically endangered species, such as *Shorea palembanica* (Ashton, 1998).

Ex-situ conservation measures through the establishment of an ex-situ conservation plot and tree breeding programs, such as selecting superior trees for seed sources of tengkawang seedlings, are essential to be carried out. GWUF has planted four tengkawang-producing species namely *Shorea stenoptera*, *S. mecisopteryx*, *S. pinanga*, and *S. palembanica*, and another high-value red meranti that does not produce tengkawang fruit, *Shorea leprosula* (meranti tembaga). Planting these species in the GWUF would not only enrich tree stands in the GWUF and conserve the species but also provide a seed source for cultivation that eventually provides provisioning services through tengkawang production. Previous studies on the relationship between growth and wood quality, especially on the dynamic modulus of elasticity (MOE) and wood density, have been carried out by assessing the tree growth performance and wood quality of the five species when the stands were 7 and 9 years old. However, only 7 individual trees were assessed for each species in each measurement year (Karlinasari et al., 2018). Meanwhile, evaluation of the adaptability and suitability, as well as the wood traits of all stands of the five species in the GWUF area, has not yet been assessed. Thus, this study aimed to examine the growth performance and wood properties of five *Shorea* species i.e., *S. stenoptera*, *S. mecisopteryx*, *S. pinanga*, *S. palembanica*, and *S. leprosula*, 15 years after planting in the GWUF. The results of this study were expected to provide basic information in formulating strategies for species enrichment in GWUF specifically and the ex-situ conservation and breeding program of these species in Indonesia extensively.

II. MATERIAL AND METHOD

A. Study Site

The research was conducted at the *Shorea* spp. demonstration plot in Gunung Walat University Forest (GWUF), Cibadak and Cicantayan Subdistricts, Sukabumi Regency, West Java Province, Indonesia (Figure 1), which is geographically located between 6^{o}54'23"



Source: Harahap et al. (2018)

Figure 1. Map of the study site. (a) Map of *Shorea* spp. demonstration plot with red color for *S. palembanica* stands, blue for *S. mecistopteryx*, yellow for *S. stenoptera*, green for *S. leprosula*, and grey for *S. pinanga*; (b) Map of GWUF; and (c) Map of West Java in Java Island

S - 6°55'35" S and 106°48'27" E - 106°50'29" E (Damayanti et al., 2020). The GWUF was originally an abandoned land covering an area of 359 ha, most of which was open land, some were covered with shrubs, and several hectares were covered with *Agathis lorantifolia* stands (Yahya et al., 2015). However, since the Faculty of Forestry and Environment IPB managed GWUF in 1969, this area was then planted gradually with various tree species by the IPB students, alumni, and local communities. Currently, the forest is 95% covered with 15 tree species, including *Agathis dammara*, *Pinus merkusii*, *Schima wallichii*, *Maesopsis eminii*, *Swietenia macrophylla*, *Altingia excelsa*, *Dalbergia latifolia*, *Gliricidia* sp., *Paraserianthes falcataria*, *Shorea leprosula*, *Shorea stenoptera*, *Shorea mecisopteryx*, *Shorea pinanga*, *Shorea palembanica*, and *Acacia mangium*, and also 11 woody shrub species such as *Calliandra calothyrsus*, *Etlingera solaris*, *Clidemia hirta*, *Melastoma candidum*, *Sellaginella doederleinii*, *Cynodon dactylon*, *Curculigo latifolia*, *Claoxylon indicum*, *Leea sambucina*, *Equisetum debile*, and *Coffea arabica* (Yahya et al., 2015; Damayanti et al., 2020).

B. Species Selection and Plot Establishment

In this study, we examined five *Shorea* species; four of them are tengkawang-producing trees, namely *S. stenoptera*, *S. mecisopteryx*, *S. pinanga*, and *S. palembanica*; and one is a non-tengkawang-producing-tree, namely *S. leprosula*. These species are included in the red meranti group, which has high economic and ecological value (Newman et al., 1999). These species were selected based on different growth performance (Karlinasari et al., 2018), namely (i) fast-growing species (*Shorea leprosula*), (ii) moderate-growing species (*Shorea stenoptera* and *S. mecistopteryx*), and (iii) slow-growing species (*Shorea pinanga* and *S. palembanica*). This selection was important so as to obtain growth performance and wood properties data of these five species as a basis for determining whether these species can adapt and are suitable for the site in GWUF.

There were 26 individuals of *Shorea leprosula*, 30 individuals of *S. stenoptera*, 58 individuals of *S. mecistopteryx*, 10 individuals of *S. pinanga*, and 10 individuals of *S. palembanica* planted among existing mixed tree stands with a planting distance of 5 m × 5 m in the species trial block (06°55'0" S - 106°49'30" E) in 2006 (Figure 1a). The existing stands consist of adult trees that have a diameter at breast height (dbh) of more than 40 cm (Karlinasari et al., 2018). In total, 134 trees of *Shorea* species were evaluated in this study.

C. Data Collection

The adaptability and suitability of 15-year-old *Shorea leprosula*, *S. stenoptera*, *S. mecisopteryx*, *S. pinanga*, and *S. palembanica* planted in GWUF were evaluated by examining the tree growth parameters. Wood traits were evaluated by assessing the physical wood properties of standing trees. Tree growth parameters for each species examined in this study included (i) total tree height (m) measured using Haga Hypsometer, (ii) stem diameter (cm) at breast height (dbh 1.3 m) using measuring tape, (iii) tree volume (m^3) by calculating it using Equation 1 (Forest Area Consolidation Center Agency Denpasar VIII, 2021), and (iv) slenderness by calculating the ratio of the total height and stem diameter at breast height (Wang et al., 1998).

Tree Volume (m^3) = Tree basal area × tree height × form factor ....(1)

Where,
Tree basal area (m^2): (3.14/4) × $(dbh)^2$
Form factor: 0.7

The physical wood properties of five *Shorea* species in this study were evaluated by analyzing the wood moisture content, wood density, wood specific gravity, and pilodyn penetration. In order to measure wood moisture content, density, and specific gravity, the wood core samples from each stem were collected using a hollow punch (Prohex Germany) with a diameter of 10 mm and a length of 2-3 cm. The wet volume of the wood core (cm^3) was determined by water displacement using a graduated cylinder (Archimedes method; Cornelissen et al., 2003), while the oven-dry weight was determined by the weight of the wood core after drying in an oven at 105°C for 24 hours (Kalanatarifard & Yang, 2012) in Mycorrhiza Laboratory at Department of Silviculture, Faculty of Forestry and Environment, IPB University, Bogor. This oven-dry weight was then used to calculate moisture content (%) by using Equation 2 (Hartley & Marchant, 1995). Whereas, the wet volume was used to calculate the wood density (g/cm^3) by using Equation 3 (Zabel et al., 2020) and wood specific gravity by using Equation 4 (Simpson, 1993).

Wood Moisture Content (%) = ((Green weight – oven-dry weight)/oven-dry weight) × 100 % ....(2)

Wood Density (g/cm^3) = Green weight/wet volume of the wood core ....(3)

Wood Specific Gravity = ((Wd/Vg)/ρ) ....(4)

Where,
Wd: oven-dry weight of the wood core
Vg: wet volume of the wood core
ρ: water density (1 g/cm^3)

In addition, the pilodyn penetration parameter was also used in this study to evaluate the wood density of the standing tree. Pilodyn penetrometer 6J was used to measure the penetration depth of a spring-loaded blunt pin (2.5 cm diameter) fired into the tree stem at breast height (1.3 m) without removing the bark with an exact force to a maximum depth of 40 mm (Gregory et al., 2007; Fundova et al., 2018).

D. Statistical Data Analysis

The data of growth parameters and physical wood properties parameters, including tree height, stem diameter at breast height, tree volume, slenderness, wood moisture content, wood density, wood specific gravity, and pilodyn penetration, were interpreted by using a box-plot analysis to determine the data distribution of each parameter. The analysis of variance (ANOVA) at the 5% level of significance was performed to observe the variation between each species and each growth parameter as well as physical wood properties parameters. Further analysis using the Duncan multiple range test at the 5% level was also performed if there was a significant difference in observed variables (Sumida et al., 2013). Those analyses were performed using SPSS software (IBM Corp., 2020). In addition, the relationship among parameters was analyzed using Pearson Correlation Analysis, which was performed using SPSS software (IBM Corp., 2020), and the Principal Component Analysis (PCA), which was performed using Minitab software version 16 (Minitab, 2021).

III. RESULTS AND DISCUSSION

A. Tree Growth Performance of 15-Year-Old Five *Shorea* Species in GWUF

Tree growth, such as the increase in dimensions of height and diameter, is a transformation process in tree life that affects stand yields (Hardjana & Suastati, 2014). The parameters related to tree growth are basic information for forest resource management and forest ecology studies (Nugroho, 2014). In the present study, the data of four parameters of tree growth, such as tree height, stem diameter, tree volume, and slenderness, were analyzed using a box-plot analysis and further variance analysis.

The box-plot analysis on stem diameter (at breast height) showed that the *Shorea leprosula* stand has the highest box position than the other *Shorea* stands with a diameter range of ±5-33 cm (Figure 2a), and the *S. palembanica* stand has the lowest box position with a diameter range of ±5-6 cm (Figure 2a). These results revealed that *S. leprosula*, as a fast-growing species, showed the highest stem-diameter growth compared to moderate-growing species and slow-growing species. While, *S. palembanica*, as a slow-growing species, showed the lowest stem diameter compared to other species. In addition, the average diameter of *S. leprosula* (19.64 cm) and *S. palembanica* (6.73 cm) was significantly different from the other species based on the Duncan test results at a 5% level (Table 1).

The high average diameter of *S. leprosula* was also reported in Karlinasari et al. (2018) study in GWUF, where 9-year-old *S. leprosula* stands had the highest and significant average diameter (9.714 cm) compared to *Shorea stenoptera* (8.857 cm), *Shorea mecisopteryx* (8.286 cm), *Shorea pinanga* (6.028 cm), and *Shorea palembanica* (6.185 cm), as well as in Istomo et al. (1999) study in Haurbentes Research Forest in West Java Province, Indonesia, where 13-year-old *S. leprosula* stands had the highest average diameter (30.65 cm) compared to *S. stenoptera* (23.63 cm) and *S. pinanga* (14.69 cm). However, the average diameter of 13 years old *S. leprosula* stands in Haurbentes Research Forest is better than the 15-year-old stand in GWUF. This pattern is possible considering that the *Shorea* species grown in Haurbentes Research Forest were planted in bare land that was not shaded by other large tree crowns that had been planted prior to *Shorea* planting. Unlike, the five *Shorea* species grown in GWUF were planted between old tree stands with a diameter of more than 40 cm so that the distribution of light intensity in these stands could vary (Karlinasari et al., 2018), which then also caused variations in the stem diameter of each species (Figure 2a), even though *Shorea* spp. is a species that requires shade in the seedling phase and more sunlight to grow to the next phase (Krisnawati & Wahjono, 2010; Wistara et al., 2016). Seedlings of *Shorea* spp. grow well on the forest gap with light intensity between 42.71% to 45.73% or 52.1% to 55% (the Spherical Crown Densiometer scale) (Stuckle et al., 2001; Wahyudi et al., 2016). Therefore, silvicultural treatment such as removing the closest competitor trees, called thinning, is needed for future stand maintenance activities to provide better growth space, including increasing the spacing and reducing competition for light, nutrients, and minerals to stimulate the growth of *Shorea* stem diameter (Krisnawati & Wahjono, 2010; Wistara et al., 2016; Indrioko et al., 2020; Pamoengkas et al., 2020).

The distribution of tree height data of five *Shorea* species based on box-plot analysis showed that *Shorea leprosula* stand has the highest box position compared to the other species, with a tree height range of ±11-32 m (Figure 2a), and *S. palembanica* stand has the lowest box position compared to the other species with a tree height range of ±9-13 m (Figure 2a). However, the average tree height showed that *S. stenoptera* was higher (23.35 m) and significantly different from other species, followed by *S. leprosula* (22.38 m) (Table 1), while *S. palembanica* was lower (11.15 m) and significantly different from other species (Table 1). This pattern was slightly different from the results of Karlinasari et al., (2018) study in GWUF, where 9-year-old *S. leprosula* showed a higher and significant average tree height (13.271 m) compared to *S. stenoptera* (8.857 m), *S. mecisopteryx* (8.286 m), *S. pinanga* (5.971 m) and *S. palembanica* (5.457 m). In addition, the current pattern was also slightly different from Istomo et al., (1999) study in Haurbentes Research Forest in West Java Province, Indonesia, where 13-year-old *S. leprosula* stands has the greater average tree height (19.88 m) compared with *S. stenoptera* (16.15 m) and *S. pinanga* stands (12.39 m).

In the present study, the tree height pattern contradicts the stem diameter pattern, especially in the case of *S. stenoptera*,. This suggests that the impact of tree height and stem diameter varies between stands and within the same stand over time (Nugroho, 2014; Curtis, 1967; Paulo et al., 2011). Differences in site quality (Larsen & Hann, 1987; Wang & Hann, 1988; Nugroho, 2014), stand density (Sharma & Parton, 2007; Temesgen et al., 2008; Nugroho, 2014), and stand age (VanderSchaaf, 2008; Nugroho, 2014) may lead to variations in stand-to-stand. However, all *Shore*a stands in this study were of the same age so the stand density was the most influential factor on stand variation. Whereas variation over time within the same stand can be attributed to the arrangement of trees in a stand (Temesgen & Gadow, 2004; Nugroho, 2014) and the spatial distribution pattern (Aguirre et al., 2003; Zhang et al., 2004).

The results of box-plot analysis on tree volume were similar to the stem diameter results, which showed that *Shorea leprosula* stand has the highest box position compared to other species, indicating the stand had a more growth stage at tree volume ±0.01-1.1 m^3 (Figure 2b), and *S. palembanica* stands have the lowest tree volume (±0.09-0.26 m^3) compared to other species (Figure 2b). Besides that, the average tree volume of *S. leprosula* was also the highest (0.27 m^3) and significantly different from other species (Table 1), while the average tree volume of *S. palembanica* (0.02 m^3) was the lowest among other species although it was not significantly different from *S. stenoptera*, *S. mecisopteryx*, and *S. pinanga* (Table 1). The current tree volume evaluation results in the three 15-year-old *Shorea* species are slightly similar to the results of the tree volume evaluation when these five *Shorea* species were 9-year-old, where *S. leprosula* showed a higher average tree volume (0.066 m^3) and *S. pinanga* showed a lower average tree volume (0.013 m^3) compared to other species (Karlinasari et al., 2018).

In order to support the results of tree height, diameter at breast height, and volume, another parameter, such as the slenderness of this tree *Shorea* species, was also determined. The distribution data on slenderness (Figure 2c, Table 1) showed that *S. stenoptera* has the highest mean value of slenderness (202.73) and was significantly different from other species, while *S. leprosula* has the lowest mean value (126.58) and is significantly different from other species (Figure 2c, Table 1). The highest value of *S. stenoptera* indicated that the stand of this

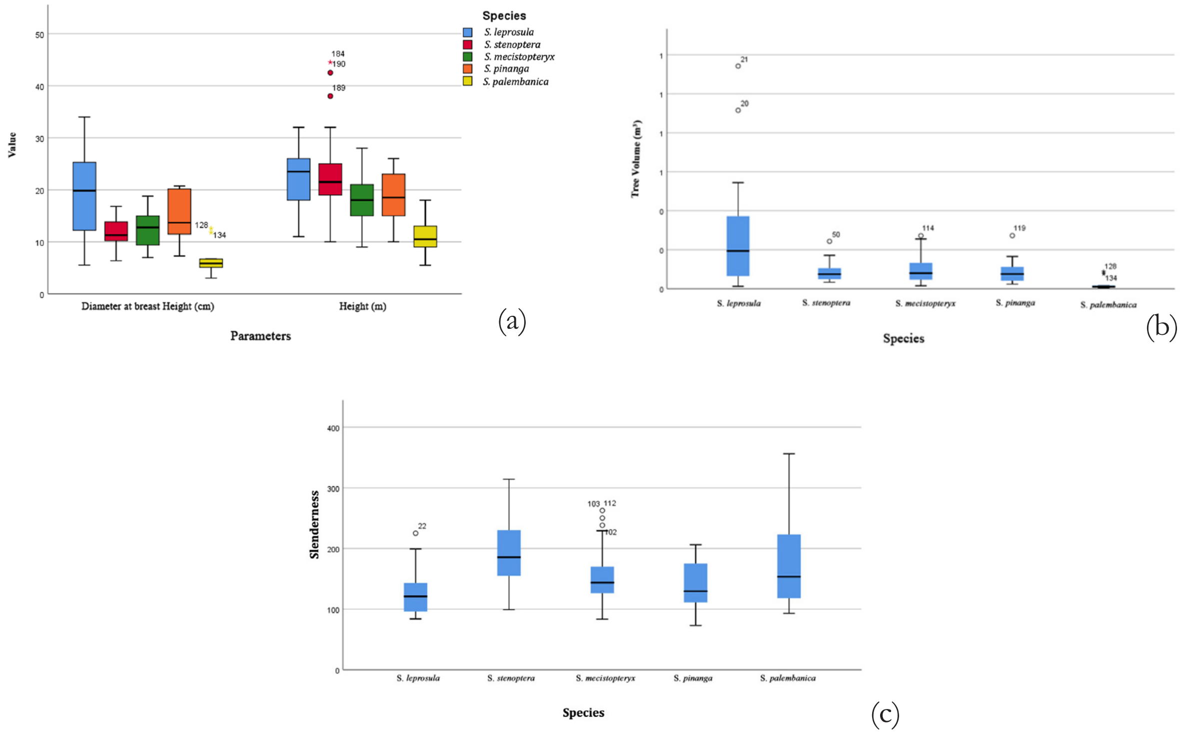


Figure 2. Box-plot diagram of *Shorea* spp. tree growth (open circle: outliers). (a) Stem diameter and tree height, and (b) Tree volume, and (c) Slenderness in each *Shorea* species

Table 1. Mean values of 15-year-old *Shorea* spp. growth parameters

Growth Rate	Species	n	Diameter (cm)	Height (m)	Tree Volume (m^3)	Slenderness
Fast	*Shorea leprosula*	26	19.64[c] (±8.179)	22.38[cd] (± 5.441)	0.27[b] (±0.276)	126.58[a] (±37.200)
Moderate	*Shorea stenoptera*	30	11.86[b] (± 2.461)	23.35[d] (±7.742)	0.09[a] (±0.048)	202.73[c] (±69.865)
Moderate	*Shorea mecistopteryx*	58	12.47[b] (± 3.316)	18.17[b] (±4.419)	0.10[a] (± 0.066)	151.15[ab] (±38.808)
Slow	*Shorea pinanga*	10	14.45[b] (± 4.655)	18.70[bc] (±4.809)	0.09[a] (±0.077)	136.90[a] (±39.909)
Slow	*Shorea palembanica*	10	6.73[a] (± 3.040)	11.15[a] (±4.096)	0.02[a] (±0.031)	186.00[bc] (±91.658)

Notes: Mean ± standard deviation (SD) with different letters in the same column indicate significant differences at $P<0.05$ (Duncan's test); n = number of samples.

species is dominated by the slender tree shape, which is generally susceptible to wind damage (Wang et al., 1998). While the lowest value of *S. leprosula* indicated that the stand has an ideal proportion of height and stem diameter and might have a longer crown (Wang et al., 1998). However, the tree slenderness coefficient can also change with age and site (Rottman, 1986); for example, tree slenderness increases in young trees, culminates, and then gradually decreases in softwood species (Konopka et al., 1987), and it also increases on better quality sites (Oliveira, 1987).

B. Physical Wood Properties of 15-Year-Old *Shorea* Species in GWUF

Moisture content, wood density, specific gravity, and pilodyn penetration are physical properties that need to be considered in wood utilization (Wistara et al., 2016). In this study, the results of the moisture content of five *Shorea* species showed that *S. palembanica* stand has the highest box position (Figure 3a) and the highest average moisture content (92.87%) compared to other species (Table 2). The average of *S. palembanica*'s moisture content also showed statistically significant differences among species, suggesting that the stand had the highest moisture content. While *S. pinanga* stand has the lowest box position (Figure 3a) and average moisture content (66.10%) compared to other species (Table 2) indicated the stand had the lowest moisture content.

In the case of wood density evaluation of five *Shorea* spp. in GWUF showed that *Shorea leprosula* stand has the highest box position (Figure 3b) and the highest average wood density (0.92 g/cm^3) compared to other species (Table 2). The *S. stenoptera* stand has a moderate box position (Figure 3b) and moderate average wood density (0.90 g/cm^3) compared to other species (Table 2), that the stand had a moderate wood density. Besides that, the *S. palembanica* stand has the lowest box position (Figure 3b), and average wood density (0.87 g/cm^3) compared to other species (Table 2) which indicated the stand had the lowest wood density. However, the wood density in the studied *Shorea* spp. was not significantly different based on the Duncan test at a 5% level of significance.

The specific gravity evaluation in this study showed that the *Shorea pinanga* stand has a moderate box position (Figure 3c) but has the highest and significant average specific gravity (0.59) compared to other species (Table 2), indicating the stand had the highest specific gravity. While, *S. palembanica* stand has the lowest box position (Figure 3c) and average specific gravity (0.45) compared to other species (Table 2) indicated the stand had the lowest specific gravity. Besides moisture content, wood density, and specific gravity, the pilodyn penetration parameter was also determined, and the results showed that *S. stenoptera*, as a moderate-growing

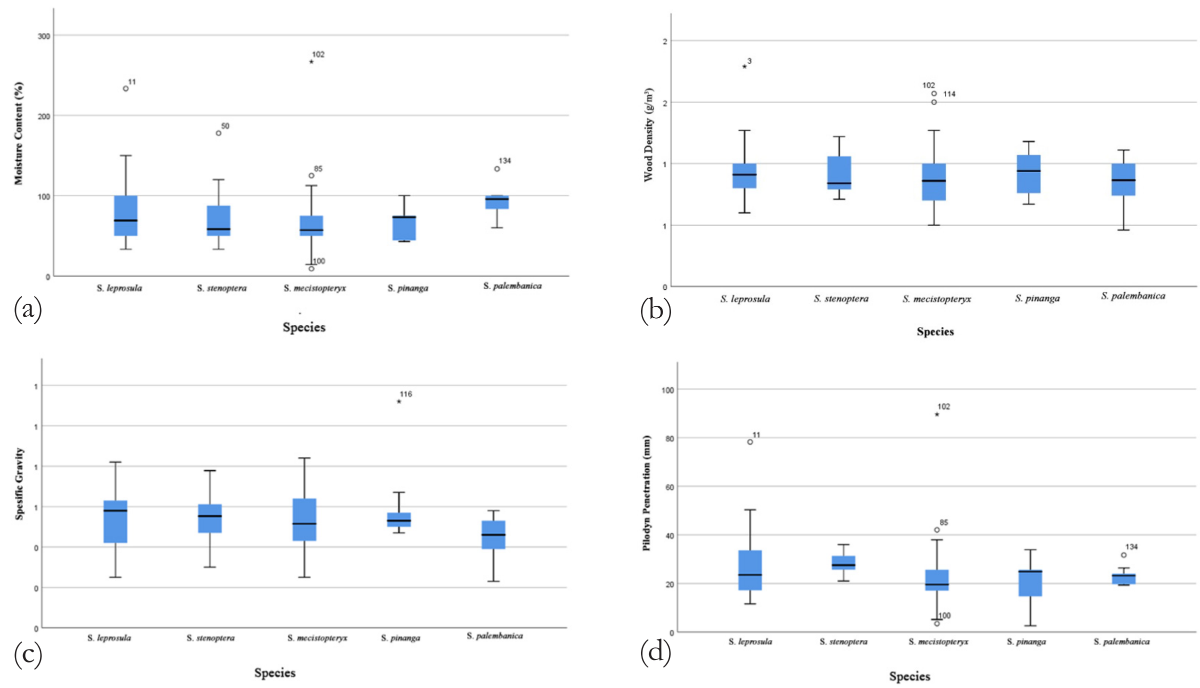


Figure 3. Box-plot diagram of *Shorea* spp. physical wood properties (open circle: outliers).
(a) Moisture content, (b) Wood density, (c) Specific gravity, and
(d) Pilodyn penetration in each *Shorea* species

Table 2. Mean values of 15-year-old *Shorea* spp. physical wood properties

Growth Rate	Species	n	Moisture Content (%)	Wood Density (g/cm^3)	Specific Gravity	Pilodyn Penetration (mm)
Fast	*Shorea leprosula*	26	81.79^a (±44.532)	0.94^a (± 0.024)	0.54^{ab} (±0.150)	27.82^a (±14.826)
Moderate	*Shorea stenoptera*	30	69.89^a (± 29.004)	0.90^a (± 0.011)	0.54^{ab} (± 0.120)	28.32^a (± 3.444)
Moderate	*Shorea mecistopteryx*	58	65.74^a (±35.410)	0.88^a (± 0.022)	0.54^{ab} (±0.127)	22.38^a (±11.825)
Slow	*Shorea pinanga*	10	66.10^a (± 19.419)	0.92^a (±0.031)	0.59^b (± 0.194)	20.96^a (± 9.056)
Slow	*Shorea palembanica*	10	92.87^b (± 19.689)	0.87^a (± 0.122)	0.45^a (± 0.107)	23.18^a (± 3.770)

Notes: Mean ± standard deviation (SD) with different letters in the same column indicate significant differences at $P<0.05$ (Duncan's test); n = number of samples

species, has the highest mean value (28.32 mm) but was not significantly different from the other species, while *S. pinanga* as a slow-growing species has the lowest mean value (20.96 mm) and was not significantly different from the other species (Figure 3d, Table 2).

Physical wood properties of 15 years old *Shorea leprosula*, *S. stenoptera*, *S. mecisopteryx*, *S. pinanga*, and *S. palembanica* planted in GWUF indicated by moisture content, wood density, and specific gravity, and pilodyn penetration revealed that the pattern of moisture content in the present study was the same as the evaluation results when the stands were 9 years old, where *S. palembanica* had high moisture content (82.57 %) compared to other species (Karlinasari et al., 2018). This study was also in accordance with other studies, which reported that wood properties such as wood density and moisture content depend on the plant growth rate. In general, slow-growing trees have higher wood density compared to fast-growing trees (Barajas-Morales, 1987; Evans, 1992; Suzuki, 1999; Muller-Landau, 2004). The decrease in wood density due to the increase in growth rate that occurs in subtropical wood is caused by the acceleration of earlywood formation compared to latewood (Jaakkola et al., 2006), thereby increasing the proportion of earlywood to latewood (Peltola et al., 2007). In addition, pilodyn penetration results in this study are also in accordance with other studies, which reported that the lower wood density, such as *Shorea leprosula*, the higher pilodyn penetration as the hardness in xylem or wood was related to wood density (Anna et al., 2020; Chen et al., 2015).

C. Correlation Analysis between Growth and Physical Wood Properties Parameters of Five *Shorea* Species in GWUF

In this study, the Pearson correlation analysis was performed to determine the relationship between growth parameters and physical wood properties parameters. The result (Table 3) showed that the height has a positive and significant correlation (confidence level of 0.01%) with stem diameter (correlation coefficient r = 0.551), volume (r = 0.534), and slenderness (r = 0.235). The diameter has a positive and very strong correlation with volume (r = 0.859) and a weak correlation with specific gravity (0.310). The tree volume has a positive and strong correlation with specific gravity (0.235). The slenderness has a positive and weak correlation with moisture content (r = 0.227) and wood density (0.234).

On the other hand, specific gravity negatively and strongly correlates with moisture content (r = -0.424). This pattern was possible because

Table 3. Statistical analysis of Pearson correlation between growth parameters and physical wood properties parameters of five *Shorea* species

Pearson Correlation	Height (m)	Diameter (cm)	Volume (m^3)	Slenderness	Moisture Content (%)	Wood Density (g/cm^3)	Specific Gravity	Pilodyn Penetration (mm)
Height (m)	1	0.551**	0.534**	0.253**	0.069	-0.498**	0.103	0.070
Diameter (cm)		1	0.859**	-0.523**	-0.153	-0.470**	0.310**	-0.110
Volume (m^3)			1		-0.151	-0.315**	0.235**	-0.164
Slenderness				1	0.227**	0.243**	-0.139	0.173*
Moisture Content (%)					1	0.088	-0.424**	0.878**
Wood Density (g/cm^3)						1	-0.110	-0.009
Specific Gravity							1	-0.337**
Pilodyn Penetration (mm)								1

Notes: ** = correlation is significant at the 0.01 level (2-tailed), and * = correlation is significant at the 0.05 level (2-tailed).

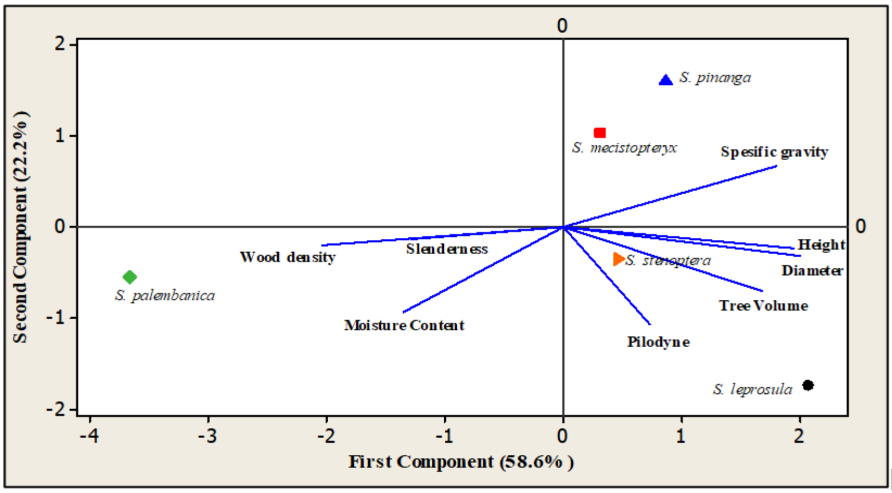


Figure 4. PCA analysis results of five *Shorea* species' growth parameters (height, diameter, volume, and slenderness) and physical wood properties parameters (moisture content, wood density, specific gravity, and pilodyn penetration

when the lumen volume is low, the moisture content becomes restricted, and the specific gravity is high (Simpson, 1993). Wood density has also a negative and moderate correlation with height (r = -0.498), diameter (r = -0.470), and volume (r = -0.315). A negative correlation between growth in height and diameter with wood density also occurs in some tropical wood species (Muller-Landau, 2004). This is because wood with low density tends to be less tolerant of shade (King et al., 2006). In addition, at the early growth stage, cellulose and hemicellulose are more dominant than lignin, which has a dominant role in vertical tree growth (Dhaka et al., 2020). In the next stages, when tree growth has reached the maximum, lignin will play a role in horizontal growth. Therefore, the higher the wood density, the smaller the height and diameter of the tree.

Besides that, pilodyn penetration has also a negative and significant correlation with specific gravity (r = -0.337) but has a positive and strong correlation with moisture content (r = 0.878). This was also reported in the research of Anna et al. (2020), where a decrease in penetration depth indicates an increase in the density and specific gravity. This is influenced by the age of the tree and the type of wood formed, which the youngest tree is still dominated by juvenile wood, and when the tree is old, it will have a xylem or wood mass that is harder and has good growth (Hidayati et al., 2013).

The relationship between growth parameters and physical wood properties parameters in this study was also analyzed using Principal Component Analysis (PCA) (Figure 4). The results showed that slenderness, wood density, and moisture content were the parameters that affected the *S. palembanica* growth performance. Besides that, height, diameter, tree volume, and pylodin penetration were the parameters that affected the *S. leprosula* and *S. stenoptera* growth performance. While specific gravity was the parameter that affected the *S. mecisopteryx* and *S. pinanga* growth performance.

The Pearson correlation analysis between growth performance and physical wood properties of five *Shorea* species in the present study showed that there was a positive and significant correlation among growth parameters such as height, stem diameter, volume, and slenderness, and there was also a positive and significant correlation among physical wood properties such as moisture content, wood density, specific gravity, and pilodyn penetration. Besides that, the physical wood properties such as wood density have also shown significant but negative correlation with growth parameters such as height, diameter, and volume. These patterns were in accordance with another study, such as *Neolamarckia cadamba* (Anna et al., 2020), which reported the correlation between pilodyn penetration and height, diameter, wood density, specific gravity, and moisture content. A strong and positive correlation between height, diameter, and volume on depth penetration of pilodyn was also found in several other wood species such as *Eucalyptus urophylla* in China (Wei & Borralho, 1997), *Acacia mangium* (Hidayati et al., 2019), and some species of hardwoods (Wu et al., 2011; Hidayati et al., 2013). In addition, the Principal Component Analysis in the present study showed that the growth performance of each *Shorea* species planted in GWUF was influenced by different parameters. Therefore, this parameter should be considered when planting these five Shorea species.

IV. CONCLUSION

The study revealed that *Shorea leprosula* showed the best growth performance and physical wood properties in terms of average diameter (19.64 cm), volume (0.27 m^3), slenderness (126.58), and wood density (0.94 g/cm^3); and *S. stenoptera* in terms of average height (23.35 m). While *S. palembanica* showed poor growth performance and physical wood properties in terms of average diameter (6.73 cm), height (11.15 m), volume (0.02 m^3), wood density (0.87 g/cm^3), and specific gravity (0.45); and *S. stenoptera* in terms of slenderness (202.73). In addition, significant differences in the tree height, diameter, volume, wood density, specific gravity, and moisture content were found in *S. palembanica* compared with other species.

This study also revealed the relationship between growth parameters and physical wood properties parameters in each species, which showed that slenderness, wood density, and moisture content could affect the growth performance of *S. palembanica*. Height, diameter, tree volume, and pilodyn penetration could affect the growth performance of *S. leprosula* and *S. stenoptera*. In addition to that, specific gravity could affect *S. mecisopteryx* and *S. pinanga* growth performance. This finding indicated that planting the four species of tengkawang trees (*Shorea stenoptera*, *S. mecisopteryx*, *S. pinanga*, and *S. palembanica*) and meranti tembaga (*Shorea leprosula*) in GWUF is suitable to increase land coverage as well as conserve the species, although the growth performance and physical properties differ between species, especially *S. palembanica*, which grew slowly. Besides that, the relationship between growth parameters and wood properties revealed in this present study must also be considered in the species selection strategy in future planting planning and the utilization of each species.

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THE ROLE OF TRADITIONAL FARMER MANAGEMENT ON THE PERFORMANCE OF PRIVATELY OWNED FORESTS: CASE STUDY IN CIAMIS REGENCY, WEST JAVA, INDONESIA

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THE ROLE OF TRADITIONAL FARMER MANAGEMENT ON THE PERFORMANCE OF PRIVATELY OWNED FORESTS: CASE STUDY IN CIAMIS REGENCY, WEST JAVA, INDONESIA. Privately owned forests (POF) play an important role in Indonesia's social, economic, and environmental spheres. The success of optimizing their roles relies on the traditional management practices carried out by farmers. Therefore, this study aimed to explore POF traditional management by farmers, POF performance, and their influencing factors. Respondents included 170 farmers selected by simple random sampling and key informant. This study was conducted in three villages across Ciamis Regency, West Java, in 2022. Data was collected through structured questionnaires, in-depth interviews, and field observations. The collected data was tabulated, graphic, categorized, and descriptively analyzed. The results showed that although the knowledge about POF management was constantly developing, not all farmers applied their knowledge. POF management practices were found to be closely related to marital status, farming experience, land area, distance from home, number of parcels, and income. Furthermore, traditional management practices were reflected in POF performance; the higher the management level, the better the performance, and vice versa. Equitability and efficiency were high across all locations; productivity was low, while sustainability was only high in Kalijaya Village. The different conditions of each element of POF, show that although POF might not be optimal in terms of economic contribution, its sustainability provides environmental benefits. This study has many limitations as it only looks at factors within POF farmers that influence POF management and performance. Further research into external factors that can influence POF performance and encourage an increased economic role for POFs can be explored in more depth.

Keywords: Knowledge, productivity, sustainability, equitability, efficiency

PERAN PENGELOLAAN TRADISIONAL PETANI PADA PERFORMANSI HUTAN RAKYAT: STUDI KASUS KABUPATEN CIAMIS, JAWA BARAT, INDONESIA. Hutan rakyat memainkan peran penting secara sosial, ekonomi, dan lingkungan di Indonesia. Keberhasilan peran hutan rakyat bergantung pada praktik pengelolaan yang dilakukan petani. Oleh karena itu, penelitian ini bertujuan untuk mengetahui pengelolaan hutan rakyat secara tradisional oleh petani, performansi hutan rakyat, dan faktor-faktor yang mempengaruhinya. Responden dalam penelitian ini adalah petani yang dipilih secara simple random sampling sebanyak 170 orang dan beberapa informan kunci. Penelitian ini dilakukan di tiga desa di Kabupaten Ciamis, Jawa Barat, pada tahun 2022. Pengumpulan data dilakukan melalui wawancara terstruktur dengan menggunakan kuesioner, wawancara mendalam, dan observasi lapangan. Data yang diperoleh diolah dengan tabulasi, grafik, kategorisasi, dan dianalisis secara deskriptif. Hasil penelitian menunjukkan bahwa pengetahuan tentang pengelolaan hutan rakyat terus berkembang, namun tidak semua petani menerapkan pengetahuannya.

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Praktik pengelolaan hutan rakyat berkaitan erat dengan pengalaman usaha tani, luas lahan, jarak dari rumah, jumlah persil lahan, dan pendapatan. Praktik pengelolaan tradisional tercermin pada performansi hutan rakyat, semakin baik tingkat pengelolaan maka semakin baik performansinya, begitu pula sebaliknya. Unsur keadilan dan efisiensi performansi hutan rakyat tergolong tinggi sedangkan unsur produktivitas rendah di semua lokasi. Sementara itu, unsur keberlanjutan hanya tinggi di Desa Kalijaya. Perbedaan kondisi elemen performansi hutan rakyat menunjukkan bahwa meskipun hutan rakyat tidak selalu memberikan hasil yang optimal secara ekonomi, namun tetap memberikan manfaat bagi lingkungan. Penelitian ini memiliki banyak keterbatasan karena hanya melihat faktor internal petani yang mempengaruhi pengelolaan dan performansi hutan rakyat. Penelitian lanjutan mengenai faktor eksternal yang dapat mempengaruhi performansi hutan rakyat dan mendorong peningkatan peran ekonomi hutan rakyat dapat dieksplorasi lebih mendalam.

Kata kunci: *Pengetahuan, produktivitas, keberlanjutan, keadilan, efisiensi*

I. INTRODUCTION

Privately owned forests (POFs) in Indonesia are reported to have undergone substantial development over an extended period (Achmad et al., 2022). The progression is closely linked to government support aimed at fostering diverse vegetation through initiatives such as reforestation, Karang Kitri, and Rakgantang (Gandrung Tatangkalan) programs (Awang et al., 2007; Hardjanto et al., 2022). Furthermore, POF as private property rights built on privately-owned land have continued to follow market trends naturally without intervention from any party (Hardjanto et al., 2022; Hardjanto & Patabang, 2019; Nugroho & Tiryana, 2014; Parlinah et al., 2020). All management practices including planting, maintenance, harvesting, and marketing rest solely on the individual or family, guided by autonomous decisions based on personal needs (Trison, 2012). The decision-making of landowners regarding their land is influenced by place-attachment values, land and wildlife management beliefs, the purpose of resource ownership (Balukas et al., 2019), economic and environmental factors (Rahmani et al., 2021, 2022), attitude towards risk (Wang et al., 2022), as well as market and policies (Matilainen et al., 2023; Nurrochmat et al., 2021).

Farmers can manage POF based on knowledge (Awang et al., 2007; Pynnönen et al., 2019). Adequate knowledge is needed to actualize the purpose of POF for farmers and industry (Awang et al., 2007; Pynnönen et al., 2019). However, Floress et al. (2019) stated that knowledge is not the only important determinant of farmer behavior in forest management, but it contributes economically to farmers' income, provides an opportunity to reduce unemployment by absorbing labor in the village, and plays a role in maintaining environmental sustainability. The success of management is intrinsically linked to the local knowledge possessed by the farmers. Local knowledge can also have significant changes along with the development of information technology

POF are closely related to their owners, hence, villagers' patterns of cultivation, use, and interactions vary depending on soil fertility conditions, community culture, and local policies (Awang et al., 2007). According to Suharjito et al. (2000), the existence of POF is shaped not only by natural interactions between botanical components, microorganisms, soil minerals, water, and air but also by the role of humans and culture. Anen (2017) stated that cultural habits and local knowledge influenced the development of POF. Local resource users can dynamically combine traditional and oral knowledge (Joa & Schraml, 2020). The planting pattern often follows monoculture and agroforestry approaches. However, the selection of both timber and non-timber plant types is adapted to local biophysical (ecological), social, cultural, and economic factors.

The development of POFs will be reflected in their performance, and the performance of POFs depends on their management practices. There have been many studies related to POF management in different aspects, but not related to the performance of POFs. There have been many studies related to POF management in different aspects, but not related to the performance of POFs. A lot of different things are looked at in these studies, such as farmer involvement in POF management (Hudiyani, 2015; Sudrajat et al., 2016), farmer motivation (Nurdina et al., 2015; Suherdi et al., 2015), marketing ((Kusuma et al., 2020; Purwawangsa et al., 2021), the role of POFs (Irawanti et al., 2012b; Oktalina, 2015; dan Achmad et al., 2015), institutions (Nugroho, 2010); Ruhimat, 2016), and (Purbawiyatna et al., 2011; Sukwika et al., 2018; Maryudi and Nawir, 2017). Research on the performance of POFs by Anen (2017) is only concerned with management conditions and POF performance; it does not explain the connection between the two and the various other factors that affect them. This study not only examines POF management practices and performance but also to explaining how management and performance relate using (Conway, 1987) performance concept approach. This study aimed to knows POF traditional management by farmers, POF performance, and their influencing factors.

II. MATERIAL AND METHOD

A. Location

This study was conducted in Ciamis Regency, West Java, Indonesia, geographically located between 108°19'–108°43' East Longitude and 7°40'30"- 7°41'30" South Latitude. The established boundaries of the regency are as follows: North-Majalengka and Kuningan; West-Tasikmalaya/Tasikmalaya Municipality; South-Pangandaran; East-Banjar Municipality and Cilacap. Covering a total area of 1,597.67 km^2, the regency is located 124 km away from the capital of West Java Province, Bandung Municipality. The administrative region is divided into 27 subdistricts, and 258 villages (Badan Pusat Statistik Kabupaten Ciamis, 2022a).

The consideration for the selection of the research site is that Ciamis Regency is one of the areas in West Java Province with the most significant representation of POF (Siarudin et al., 2022). POF now covers more than 30% of the total area of Ciamis Regency (Siarudin et al., 2022). Ciamis Regency is also known to have considerable POF potential as seen from the POF area and the growth of wood-based industries from POF (Cabang Dinas Kehutanan Wilayah VII Provinsi Jawa Barat, 2019; Siarudin et al., 2022; Suhartono, 2021).

Three villages were selected by purposive sampling, each representing a different geographic area and range of altitudes. The lowest plain ('lowlands') was represented by Kalijaya Village, Banjaranyar Subdistrict, in the south, while the intermediate plains ('midlands') were marked by Mekarjaya Village, Baregbeg Subdistrict, in the central area. Finally, the highest plain ('highlands') was represented by Hujungtiwu Village, Panjalu Subdistrict, in the north. Kalijaya Village has an area of 712 ha with an average altitude of less than 200 m above sea level (m asl), Mekarjaya Village has an area of 399 ha with an altitude of 200-500 m asl and Hujungtiwu Village has an area of 712 ha with an altitude of over 500 m asl (Badan Pusat Statistik Kabupaten Ciamis, 2022b, 2022c, 2022d). A map of the study location is presented in Figure 1.

B. Methods

The population studied were farmers who owned and managed POF. Data were collected through structured questionnaires, in-depth interviews, and field observations. Structured interviews were conducted with 170 farmers selected with simple random sampling. The number of farmers in each village was 55 in Hujungtiwu, 55 in Mekarjaya, and 60 in Kalijaya. This number of respondents represented the

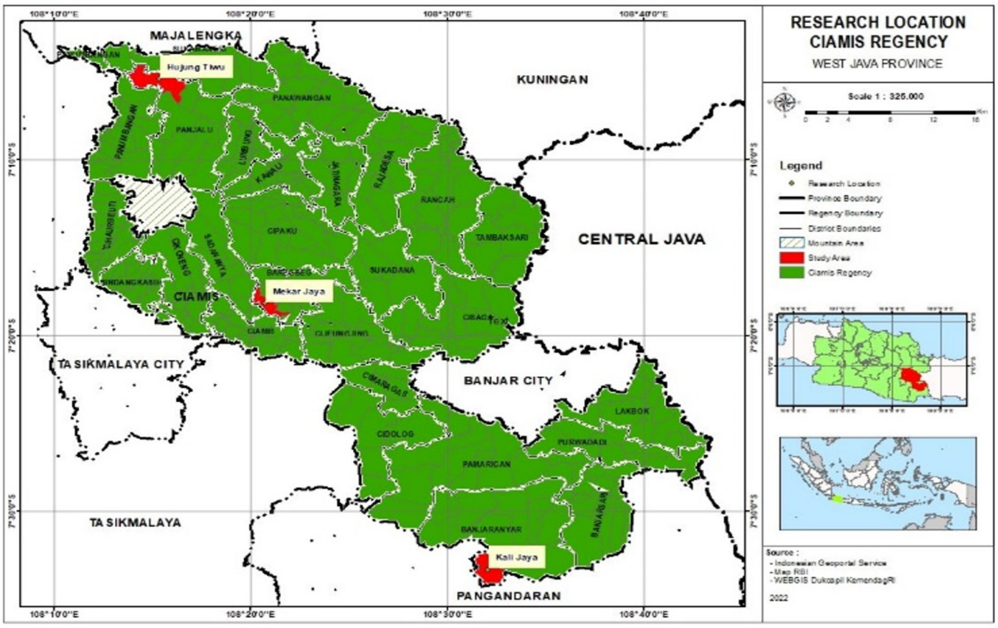


Figure 1. Study location in Ciamis Regency

population of POF farmers in the study area. This approach aligns with Cohen et al. (2007) who suggest that while a larger sample size is preferable, the minimum number should be 30. In-depth interviews were conducted with several farmers who had a deeper understanding of POF management. To ensure that the informants had an in-depth understanding to answer the questions, the researcher sought information and advice from local extension workers and village officials. Field observations were conducted through observation and documentation of several farmer-owned POFs. The data collected included respondent and POF characteristics, POF management practices, and POF performance.

POF management included three sub-systems, namely production, processing, and marketing. POF performance comprised productivity, sustainability, equitability, and efficiency (Conway, 1987). In this study, we have defined each element of POF performance based on the modified Conway concept. Productivity was defined as the yield or income of products owned/produced by farmers per unit area per year. Sustainability refers to the efforts to maintain POF including planting intensity, rejuvenation, and maintenance. Furthermore, equitability was defined as the equitable distribution of benefits from POF, measured by the number of parties benefiting. Data to measure efficiency were in the form of input (production costs) and output (production value) of farms. Efficiency is the lowest cost in managing a POF business while generating the highest income. It was measured based on the business unit level calculated on the input-output basis of production (profit from POF business income minus capital).

This study also collected a land use map for the last 20 years (2000-2020), to look at the land use (land cover) at the research site. The data was obtained from the Directorate General for Forestry Planning and Environmental Governance (Ministry of Environment and Forestry).

C. Analysis

The collected data was tabulated, graphic, and categorized. The land use data were processed using Arc View GIS software. All processed data were then descriptively analyzed according to the research objectives.

Each management activity stage and

performance element of POF was rated from 1 to 3 based on the frequency distribution intervals of the data generated from the field, as shown in Table 1 and Table 2.

The data on each stage of POF management activities and four performance elements were then grouped into three categories: low, medium, and high. The class interval was calculated using the formula (GeeksforGeeks, 2023; Widoyoko, 2015):

$$Class\ interval = \frac{highest\ score - lowest\ score}{number\ of\ classes}$$

The categories of POF management conditions and performance elements were grouped as follows; 1). low (score 1 - 1.67), 2). medium (score >1.67-2.33), and 3). high (score >2.33-3). Data were processed and analyzed using the Spearman correlation statistical test with SPSS 27 IBM for Windows to determine the correlation between farmer characteristics, POF management, and performance.

III. RESULT AND DISCUSSION

A. Characteristics of Farmers and POF

The characteristics of farmers and POF in the study areas are shown in Table 3. The table showed that the average age was over 50 years, and the education level was predominantly primary school. In addition to formal education, some farmers also receive non-formal education, such as advice and training from agricultural/ forestry extension workers, so that they have a good knowledge of POF management. Moreover, most respondents were indigenous villagers whose main livelihood was agriculture with an average farming experience of 29.1 years in all study locations. Thus, the farmers in the three research sites are dominated by farmers of productive age and with sufficient education to manage POF. This condition was found in the sub-district of Tulang Bawang by Anatika et al. (2019) who mentioned that the POF farmers are characterized by a productive age, sufficient education (formal and nonformal education), an average number of family dependents, and sufficient experience in farming.

The average land area was 1.81 ha, 0.39 ha, and 0.58 ha in Kalijaya, Mekarjaya, and Hujungtiwu Villages, respectively. When grouped into three strata, the land area was dominated by narrow land ownership with many scattered parcels. This land area was also directly proportional to income from POF, where the average in Mekarjaya Village was the lowest. Furthermore, this condition was related to land accessibility, both the distance from

Table 1. Rating of POF management

POF management stages	Parameter	Rating		
		1	2	3
Production	Activity frequency	Low	Medium	High
Processing	Activity frequency	Low	Medium	High
Marketing	Activity frequency	Low	Medium	High

Table 2. Rating of POF performance

POF performance	Parameter	Rating		
		1	2	3
Productivity	Income	Low	Medium	High
Sustainability	Maintenance activity	Low	Medium	High
Equitability	Number of beneficiaries	Low	Medium	High
Efficiency	Percentage of production cost	Low	Medium	High

Table 3. Characteristics of POF farmers in the study areas

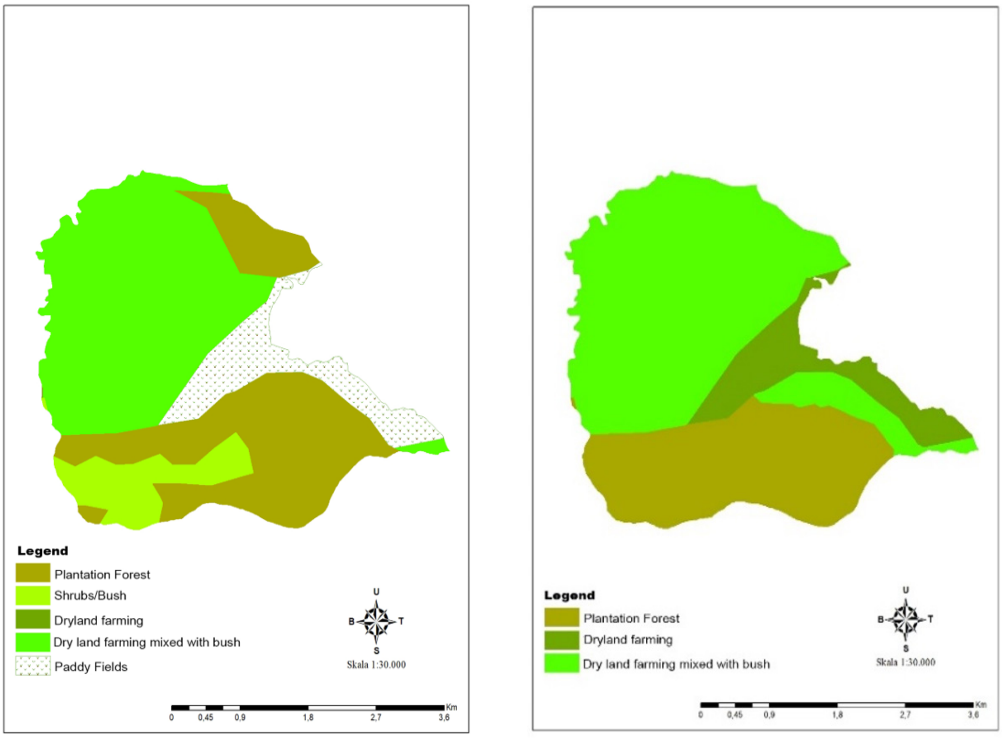
Characteristics		Percentage of respondent		
		Kalijaya	Mekarjaya	Hujungtiwu
Farmer characteristics				
Gender (%)	Male	81.67	80.00	89.10
	Female	18.33	20.00	10.90
Age (years)	Average	53.80	62.60	55.00
	Min	24.00	39.00	35.00
	Max	85.00	86.00	83.00
Education (years)	Average	7.20	8.00	7.30
	Min	2.00	1.00	5.00
	Max	16.00	18.00	19.00
Number of family dependent (person)	Average	2.00	1.50	2.10
	Min	0.00	0.00	0.00
	Max	4.00	5.00	6.00
Length of stay (years)	Average	50.20	58.80	50.40
	Min	15.00	2.00	12.00
	Max	78.00	86.00	73.00
Farming experience (years)	Average	31.70	34.53	21.11
	Min	2.00	1.00	2.00
	Max	73.00	65.00	52.00
POF characteristic				
POF land area (ha)	Average	1.81	0.39	0.58
	Min	0.14	0.04	0.01
	Max	7.79	1.43	4.09
Number of POF land parcels	Average	4.27	3.03	2.27
	Min	1.00	1.00	1.00
	Max	10.00	16.00	6.00
Distance of POF from home (km)	Average	1.98	0.67	0.83
	Min	0.01	0.01	0.05
	Max	14.00	4.00	5.00
Income of POF (IDR/years)	Average	34,274,852	5,023.264	10,768.364
	Min	2,130,000	902,000	900,000
	Max	238,700,000	31,960,000	300,750,000

their homes and access to land. The average land distance from residence was 1.31 km, with most travel modes being by foot or motorbike. The characteristics of the farmer and the POF will provide different motivations for POF management (Anatika et al., 2019).

POF is the most dominant land use in the three study areas. Based on the land use analysis for two decades, POF has increased as shown in Figures 2, 3, 4, and Table 4. In Kalijaya and Mekarjaya Villages, the increase in POF was caused by the practice of land conversion from paddy fields to POF, while in Hujungtiwu Village it was caused by the reduction of dryland farming. Land conversion in Java occurs almost every year, especially in paddy fields (Daris et al., 2018).

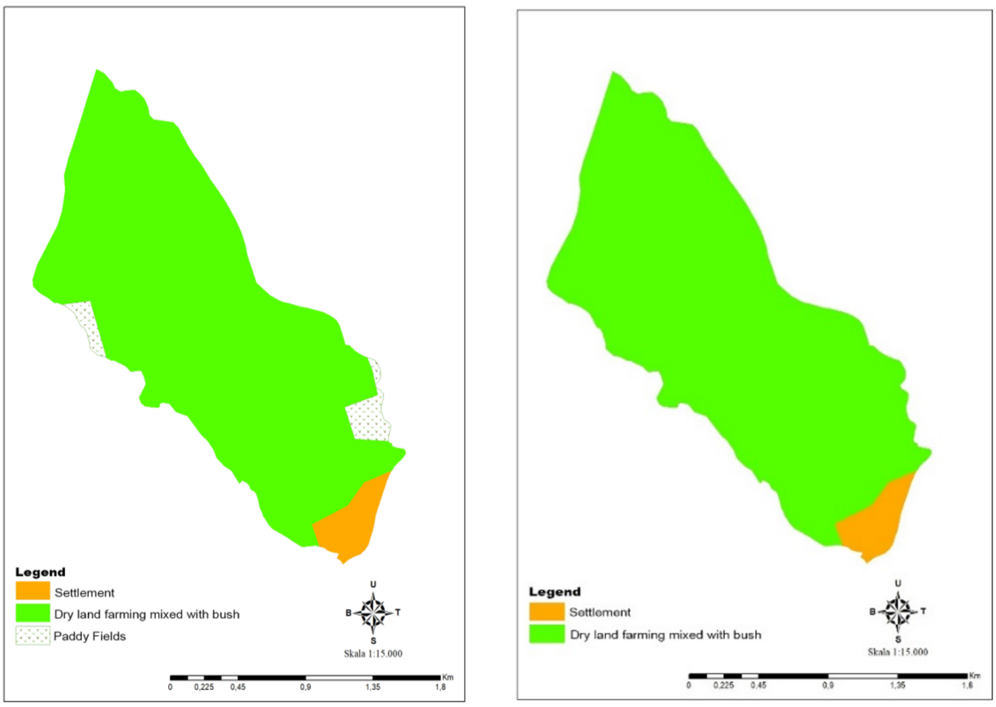
B. Traditional Knowledge and Practices in POF Management

According to many stakeholders, traditional knowledge in POF management is highly effective. Diverse forms of knowledge exist, including science-based, as well as indigenous



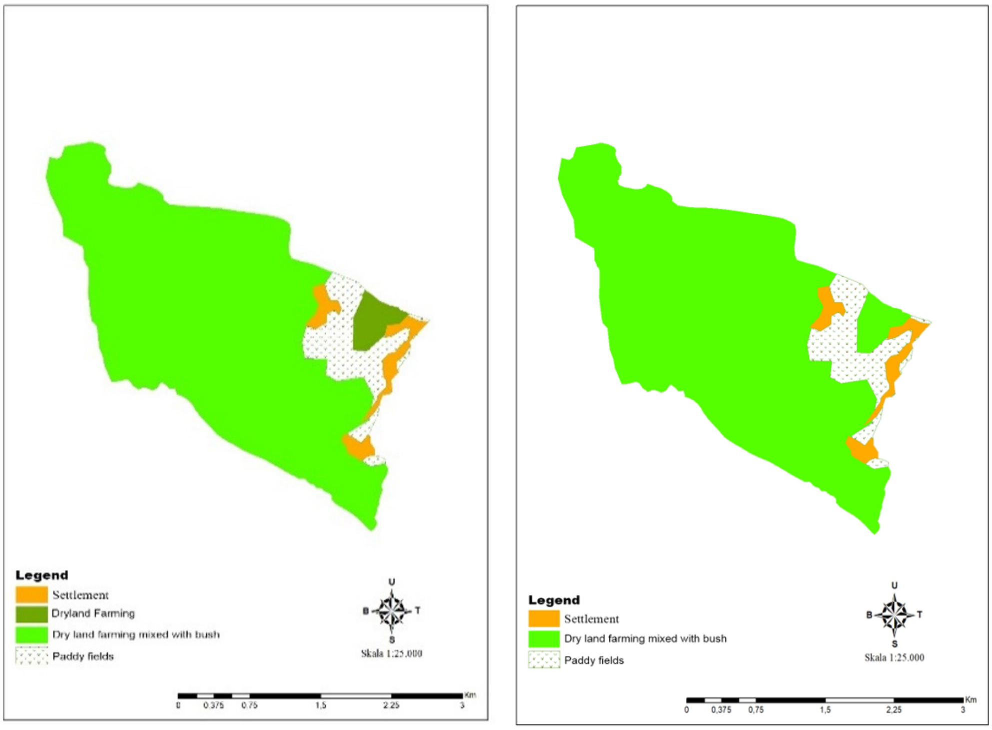
Note: POF is considered the same as dryland mixed with bush

Figure 2. Land use map in Kalijaya Village in 2000 and 2020



Note: POF is considered the same as dryland mixed with bush

Figure 3. Land use map in Mekarjaya Village in 2000 and 2020



Note: POF is considered the same as dryland mixed with bush

Figure 4. Land use map in Hujungtiwu Village in 2000 and 2020

Table 4. Land use change in research site

Land use	Land area (ha)								
	Kalijaya			Mekarjaya			Hujungtiwu		
	2000	2020	Change	2000	2020	Change	2000	2020	Change
Plantation forest	475.59	445.03	-30.56			0.00			0.00
Shrub	128.84		-128.84			0.00			0.00
Settlement			0.00	13.46	13.46	0.00	26.64	26.64	0.00
Dryland farming	0.18	166.87	166.69			0.00	19.47		-19.47
Dryland farming mixed with bush	657.52	817.10	159.58	309.95	320.57	10.63	628.14	647.61	19.47
Paddy field	166.87	0	-166.87	10.63		-10.63	63.29	63.29	0.00

Note: POF is considered the same as dryland mixed with bush.

or local (Eriksson & Fries, 2020; Hurlbert et al., 2019; IPBES, 2013). Farmers gain experience over the years by cultivating their land and achieving optimal economic, social, and ecological results (Anatika et al., 2019). This study has three subsystems in POF management: production, product processing, and marketing. Local knowledge in POF management involved understanding the types of plants suitable for the land, planting methods, preservation of certain trees, and appropriate time for harvesting. Knowledge about POF management has evolved with the development of technology and information. According to Suharjito et al. (2000), cultural habits and local knowledge influence management practices in different places. Alterations in these practices may have future consequences, affecting employment opportunities and household income (Hilsenroth et al., 2021).

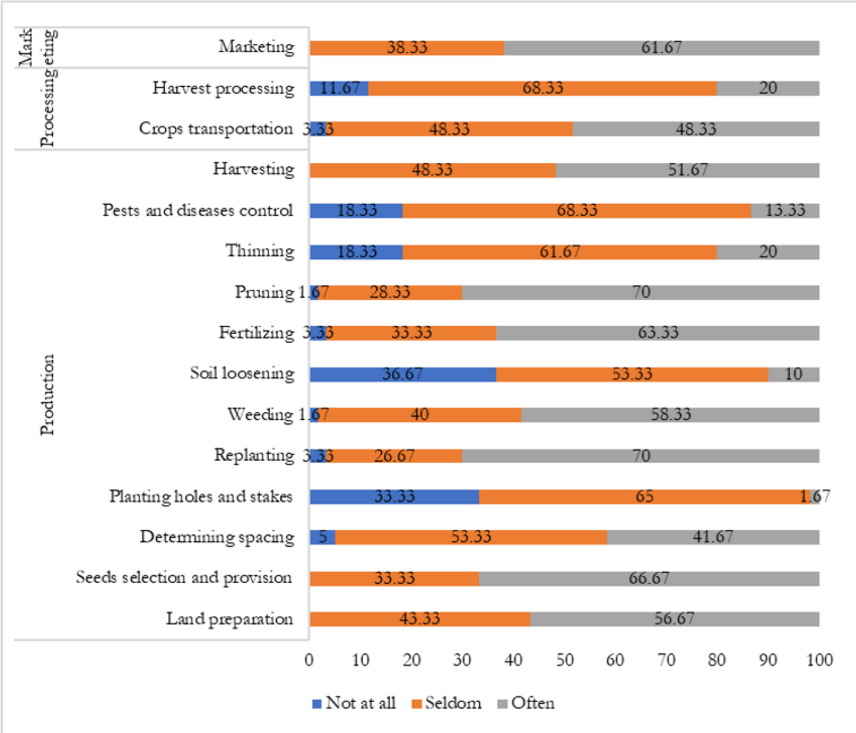


Figure 5. POF management by farmers in Kalijaya Village (%)

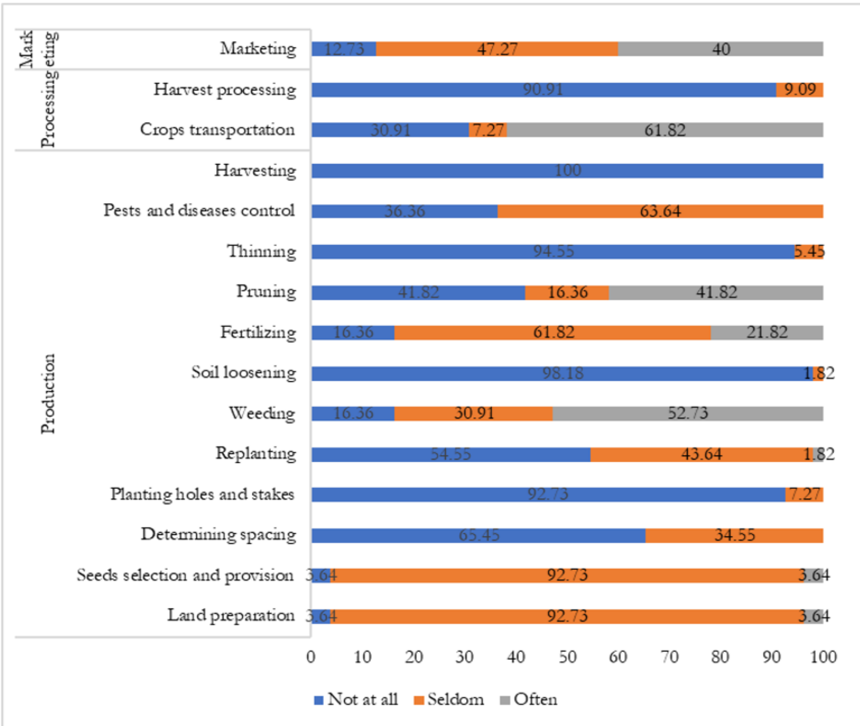


Figure 6. POF management by farmers in Mekarjaya Village (%)

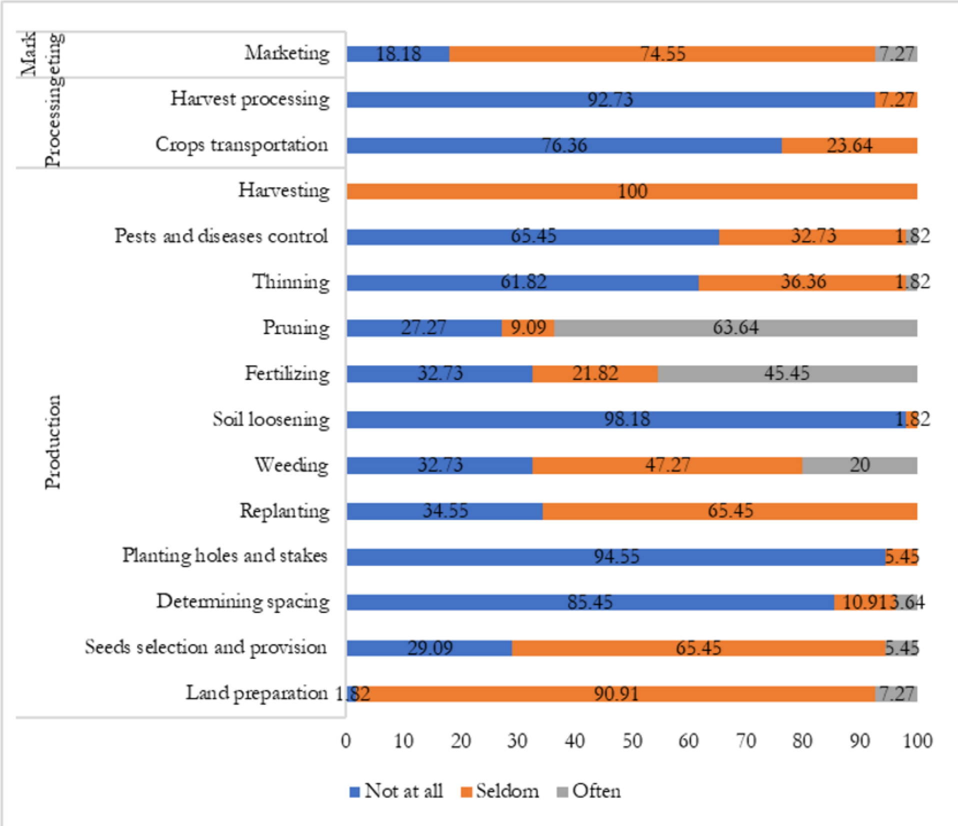


Figure 7. POF management by farmers in Hujungtiwu Village (%)

The application of knowledge and practices by farmers in POF management was found to be entirely dependent on owners. POF management in Kalijaya, Mekarjaya, and Hujungtiwu is shown in Figures 5, 6, and 7, respectively.

POF's production subsystem included planting, maintenance, and harvesting. Planting began with land preparation, selecting and providing seedlings, determining the planting spacing, making planting holes, and setting stakes. With the development of information and technology and the ease of access, farmers can also increase their knowledge of POF management, specifically on species selection, quality seed, and maintenance. However, in line with Trison (2012), not all farmers applied their knowledge to land management in this study location. The main reason why farmers do not apply their knowledge in POF management is economic constraints (capital). Farmers only carry out management activities that are considered very necessary and ignore other activities. Economic limitations also cause farmers not to make plans to manage POF land (Kurniawan, 2020). Sustainable management of forests for multiple purposes requires multifaceted socio-technical knowledge.

The selection of plants comprising POF was made according to the preferences and considerations of the landowner. Sukadaryati et al. (2018) mentioned that the planting pattern of POF management in Ciamis Regency consisted of homogeneous plants (same tree species), alongside a mixture of various timber and fruit-producing trees. The choice of cropping patterns was guided by the knowledge acquired independently or from their parents and fellow farmers. Table 5 shows that most respondents have mixed and agroforestry patterns.

The POF was mainly a type of forest ecosystem commonly established by villagers, so silvicultural prescriptions were relatively limited and carried out according to the community's

Table 5. POF cropping pattern

Cropping patterns	Percentage of respondent		
	Kalijaya	Mekarjaya	Hujungtiwu
Timber (monoculture)	3.33	1.82	7.27
Timber + MPTs	50	29.09	40
Timber + annual crops/understorey plants	23.33	67.27	45.45
Timber + MPTs + annual crops/understorey plants	21.67	0	5.45
MPTs + annual crops/understorey plants	1.67	1.82	1.82

reference (Wirabuana et al., 2021). Interestingly, most communities prefer to plant trees because of their potential financial benefits (Wirabuana et al., 2021). However, this is not entirely true as in other areas, including the study location, many farmers combine timber with non-timber crops, whether on large, medium, or small land areas.

The dominant timber species planted were sengon (*Falcataria moluccana*), teak (*Tectona grandis*), and mahogany (*Swietenia* sp.), while fruit-producing plants were diverse, including avocado (*Persea americana*), durian (*Durio zibethinus*), mangosteen (*Garcinia mangostana*), dog fruit (*Archidendron pauciflorum*), and stink bean (*Parkia spesios*a). The most common understorey plants included banana (*Musa paradisiasa*), cardamom (*Amomum cardamomum*), and turmeric (*Curcurma long*a). Meanwhile, the most dominant annual crops were maize (*Zea mays*), peanuts (*Arachis hypogaea*), sweet potato (*Ipomoea batatas*), and cassava (*Manihot esculenta*).

Farmers mostly practiced timber monoculture on land far from their homes. The diversity of cropping patterns and management practices adopted by the farmers showcased their pragmatic approach to adapting to different conditions and desired needs. Farmers with limited land tended to use a variety of cropping patterns to secure daily livelihoods (subsistence). Some farmers also opted for monoculture cropping patterns of annual crops or agroforestry with very little wood composition. Meanwhile, those with large areas tended to use mixed models, combining annual crops with multipurpose plants (MPTs), or establishing mixed plantations such as rubber (*Hevea brasiliensis*), cocoa (*Theobroma cacao*), cardamom, and coffee (*Coffea*), aiming to meet their subsistence needs and commercial purposes. Differences in cropping patterns and crop types led to yield variations and affected incomes.

Maintenance activities included replanting, weeding, soil loosening, fertilizing, pruning, thinning, and pest and disease control. Farmers mostly did not undertake any specific maintenance for timber plants in the three surveyed villages, while weeding, hoeing, and fertilizing were often carried out for non-timber plants. Pest and disease control was rarely practiced in the study areas. The maintenance intensity was also highly dependent on the distance of the land from home and the type of plantation.

Harvesting activities in POF were implemented for timber and other plants in the three villages. Harvesting activities in POFs were generally irregular or referred to as "need cycles" (Awang et al., 2007), and were carried out at specific times namely during celebrations and school children seasons. This practice is consistent across various POFs in Indonesia including Lampung (Anatika et al., 2019). Farmers fell timber independently or through the buyer and wholesale purchasing system. According to Sukwika et al. (2018), farmers rarely use timber harvesting technology despite the wide access. Instead, middlemen often take charge of timber harvesting processes, which include felling, skidding, and transportation to the wood processing industry. Regarding non-timbers, harvesting methods were adapted to the characteristics and cycle of each crop, for instance, in Kalijaya Village, fruit crops were typically sold through a proof and wholesale system. Meanwhile, understorey plants such as cardamom and turmeric were harvested by farmers themselves and sold to collectors in both wet and dry forms.

Most farmers did not engage in post-harvest processing, except for some non-timber crops, such as cardamom and turmeric. This process involved drying and bagging the crops for sale. Other plants were usually sold in their fresh state, as this was considered more profitable and simpler than undergoing processing.

Farmers in three study villages in the marketing subsystem had already established a presence in selling POF products. The marketing of POF products has become more open with the development of price information and marketing channels. Moreover, the increased knowledge of farmers culminated in a better bargaining position. Farmers had no difficulty in selling products harvested from POF, including timber and non-timber. The sale and purchase transaction occurred on the farm or at home, depending on the agreement with the buyers. POF products were usually sold temporarily to buyers who offered the best price.

Based on the management practices adopted by the farmers, POF management in the study location can be grouped into five typologies, as shown in Table 6.

The first typology mainly consisted of farmers with small landholdings, assuming the roles of owners, managers, and tenants. This category generally possessed enough family labor to manage their land, but silvicultural techniques were not fully implemented due to limited capital. Silvicultural techniques were majorly confined to understorey or annual crops, which constituted the main target of their activities. Farmers with small, medium, and large size areas practiced the second typology. Farmers managed their land to obtain both timber and non-timber products. Hence, the application of silviculture was directed towards both categories. Due to the limited capital, these farmers often relied on family labor, occasionally hiring additional labor for certain activities such as land preparation and weeding. The third typology was mainly composed of farmers with medium and large holdings. Farmers invest in land, but not in other capital. Therefore, planting was carried out without implementing proper silvicultural practices.

The fourth typology consists of farmers who invest in land and other capital but do not fully implement silvicultural practices due to the belief that trees do not need constant maintenance. Finally, the fifth typology comprises farmers who invest, have objectives, and apply silvicultural practices. All typologies of POF management existed in the three surveyed villages, but the first typology was most common in Mekarjaya and Hujungtiwu Villages. Given that narrow and medium-sized parcels of land make up the majority of land ownership in the three research sites, the first typology is prevalent there. The small size of the land, coupled with economic constraints, makes it difficult for farmers to apply all silvicultural techniques in the management of POFs. This condition also leads farmers to use only family labor in POF management and not aim for commercial yields. Based on the

Table 6. Typology of POF management in study location

No.	Typology of POF management	Land ownership
1.	Partial implementation of silvicultural practices, investment in family labor, no specific end yield	Small, Medium
2.	Implement silvicultural practices, invest in family labor, invest in capital	Small, Medium
3.	The owner invests only in land, has no yield target, does not apply silvicultural practices	Large
4.	The owner invests capital and has yield objective, but does not always apply silvicultural practices	Small, Medium, Large
5.	The owner invests capital, has yield objectives, and applies silvicultural practices	Medium, Large

explanation of each stage of POF management by farmers in each village, the condition of POF management in Kalijaya Village is classified as high. In contrast, it is classified as medium in the other two villages, as shown in Table 7. High POF management shows that farmers carry out the stages of activities that should be carried out in POF management.

In Kalijaya Village, the production and processing subsystems are classified as medium, while the marketing subsystem is classified as high. This is because most farmers in Kalijaya Village are involved in the production, processing, and marketing of POF products. In the other two villages, many farmers are only involved in some POF management activities, particularly maintenance. Due to low yields, many farmers do not process and sell POF products, but only use or consume them themselves (subsistence)

C. POF Performance

Performance measurement was carried out as a basis for policymakers to determine whether forest management was moving in the desired direction (Serafeim, 2020). POF performance was considered in terms of four elements, namely productivity, sustainability, equitability, and efficiency. The distribution of respondents according to these four elements is shown in Table 8. Although choosing indicators used as performance indices is important, the outcome depends on the management alternatives being compared (Pukkala, 2021).

Productivity is an important element that shows the ability of the forest to produce outputs. In all villages, most respondents had POF productivity in the low category. Table 7 shows that the distribution of respondents with high sustainability was observed in Kalijaya, while medium and low levels dominated the other two villages. The maintenance practices of POF used by most farmers in Kalijaya promote high sustainability.

The principle of equitability, as used in this study, involves treating everyone in the same situation without discrimination. The existence of POF provides a high level of equitability; the benefits provided were not only limited to owners but also buyers, hired labor,

Table 7. Management conditions of POF at the study location

POF subsystem	Score of POF management					
	Kalijaya		Mekarjaya		Hujungtiwu	
	Score	Category	Score	Category	Score	Category
Production	2.31	Medium	1.72	Medium	1.62	Low
Processing	2.08	Medium	1.09	Low	1.07	Low
Marketing	2.61	High	2.27	Medium	1.89	Medium
Total	2.34	High	1.69	Medium	1.68	Medium

Table 8. Distribution of respondents based on POF performance elements

POF performance element	Parameter/ Criteria*	Rating	Respondent distribution (%)		
			Kalijaya	Mekarjaya	Hujungtiwu
Productivity	Income (Rp/years)				
Low	900,000-100,850,000	1	95	100	98.2
Medium	100,850,000-200,800,000	2	0	0	0
High	200,800,000-300,700,000	3	5	0	1.8
Sustainability	Maintenance activity				
Low	Never (no maintenance)	1	0	25.5	21.8
Medium	Rarely (1-2 activity)	2	5	60	69.1
High	Often (more than three activity)	3	95	14.5	9.1

Table 8. Continued

POF performance element	Parameter/ Criteria*	Rating	Respondent distribution (%)		
			Kalijaya	Mekarjaya	Hujungtiwu
Equitability	Number of beneficiaries				
Low	Owner- farmers only	1	0	0	0
Medium	Farmers and buyers	2	3.3	25.45	14.55
High	Many parties (farmer, buyer, close family, distant family, neighbours, etc.)	3	96.7	74.55	85.45
Efficiency	Percentage of production cost (%)				
Low	>34.22-48.67	1	13.3	9,1	1,8
Medium	>19.78-34.22	2	28.3	30.9	30.6
High	5.33-19.78	3	58.3	60	65.5

Remark: *Based on interview data from the field

Table 9. POF performance

Performance elements	Score of POF performance					
	Kalijaya		Mekarjaya		Hujungtiwu	
	Score	Category	Score	Category	Score	Category
Productivity	1.10	Low	1	Low	1.04	Low
Sustainability	2.95	High	1.89	Medium	1.87	Medium
Equitability	2.97	High	2.75	High	2.85	High
Efficiency	2.45	High	2.51	High	2.64	High
Total	2.37	High	2.04	Medium	2.10	Medium

families, neighbors, and even the surrounding community.

POF efficiency was measured by the level of business units, calculated based on production input-output (profit from POF business income minus cost); most farmers do not allocate any specific capital (cost) to the management of POF. Typically, only maintenance and seedling costs are included in the first year of planting. Therefore, despite the low productivity, more than 60% of farmers were classified as having high efficiency in POF management. Overall, the POF performance value in Kalijaya was in the high (good) category, while Mekarjaya and Hujungtiwu were included in the medium as shown in Table 9. This difference is due to the different socio-economic and cultural conditions under which farmers manage POFs. Farmers in Kalijaya village have, on average, larger land holdings than those in other villages. Many farmers in Kalijaya village use POFs as their main source of livelihood, so they are better at managing POFs. Although productivity is still low, farmers' activities in maintaining POFs promote sustainability, equity, and high efficiency.

Based on the element of POF performance, the productivity in the three surveyed villages was low, suggesting that the yield or income generated by farmers was not optimal. Despite the low productivity, the sustainability of POF in Kalijaya and Mekarjaya was rated as high and medium, respectively. Maintaining the sustainability of POF is crucial for both the livelihoods of farmers and the environment (Puspita et al., 2021). The majority of farmers used practices that promoted sustainability, such as providing sufficient seeds for planting or replanting and harvesting with selective logging.

The sustainability of POF was also influenced by the adequate availability of seedlings for replanting (Safe'i et al., 2019). The community usually obtained seedlings in two ways namely natural seedlings in the garden and surrounding areas, and purchasing from traders. Factors that influenced seedling provision included age, experience of the farmer, and extension practices (Sudrajat et al., 2016). Seedlings were obtained through various channels including self-purchase, coppice, and ex-felled trees, or government support (Listiyawan et al., 2022). Farmers also usually replant tree species on ex-felled land, showing a growing adherence to sustainability principles in timber production. The high demand for timber must be balanced with good management to avoid threatening the sustainability of POFs (Fauzan et al., 2019).

Other important elements that served as indicators of POF performance were equitability and efficiency. According to Feliciano et al. (2017), farmers have diverse objectives in POF management, with equitability being a central pillar. The high scores of equitability in Table 8 show that POF can provide benefits to many parties, extending beyond the landowners (Sagita et al., 2019). POF in the three villages also showed high-efficiency scores, suggesting most farmers incurred low costs in the course of POF management. This was because many stages of the activities were carried out by the farmers themselves, thereby reducing labor costs.

D. Correlation Between Farmer and POF Characteristic, Management, and Performance

POF knowledge and management practices may be influenced by farmer characteristics. Table 10 shows that marital status is negatively significantly correlated with POF management. This correlation is an indication that POF management by married farmers was actually on the decrease because farmers have jobs in other sectors to meet their family needs, so their focus is not on POF management. Together with other factors such as education level, farming experience, and land ownership, marital status is the main driver of household decision-making and participation in land management (Mohammed et al., 2017; Okon et al., 2019).

In contrast to marital status, farming experience, POF land area, distance from home, number of parcels, and income is strongly positively correlated with POF management practices. Farmers with a longer farming experience, larger areas, close the POF distance, any number of parcels, and high income showed better POF management. According to Anatika et al. (2019), productive age, adequate level of education, land area, as well as social, environmental, and economic motivation influence POF management. Novais & Canadas (2010) mentioned that the land area, dominant species, availability of family labor, allocation of equipment, physical proximity to residences, age, gender, and occupation affected the management practices in different typologies.

Management practices were found to affect POF performance significantly. Table 11 shows that POF management practices carried out by farmers correlated positively with performance (the calculated correlation value was 0,554 at 0,01 significance level, 2-tailed). Therefore, good management practices culminate in optimal performance, and vice versa. High (good) POF performance was marked by several indicators such as high productivity, sustainable management, equitable practices, and efficient costs (Anen, 2017; Suharjito et al., 2000). In part, POF management is only strongly correlated with sustainability and equitability. The better the POF management, the higher the sustainability and equitability, but this is not always the case for productivity and efficiency. Even well-managed POF do not necessarily have high productivity and efficiency.

According to Suharjito et al. (2000), POF performance was influenced by the management system, business orientation, and product diversity. The management practices are related to the system of control and decision-making, whether individual or communal.

Table 10. Correlation between farmer characteristics, POF characteristic, and POF management

Farmer and POF characteristics	Correlation with POF management		
	Correlation coefficient	Sig. (2-tailed)	N
Gender	-0.037	0.636	170
Age	-0.137	0.075	170
Marital status	-0.184*	0.017	170
Education	-0.099	0.197	170
Number of family dependents	0.071	0.357	170
Length of stay	-0.148	0.055	170
Farming experience	0.202**	0.008	169
POF land area	0.446**	0.000	170
Number of land parcels	0.335**	0.000	170
Distance of POF from home	0.481**	0.000	170
Income of POF	0.544**	0.000	170

Remarks: * Correlation is significant at the 0,05 level (2-tailed).
**Correlation is significant at the 0,01 level (2-tailed).

Table 11. Correlation between POF management and POF performance

Spearman's rho correlations		Productivity	Sustainability	Equitability	Efficiency	POF performance
POF management	Correlation coefficient	0.146	0.667**	0.246**	-0.123	0.554**
	Sig, (2-tailed)	0.000	0.058	0.001	0.110	0.000
	N	170	170	170	170	170

Remarks: * Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

The tenure system and management decision-making influence the responsiveness to the market economy and social economic models. Landowning farmers played an important role in the decision-making regarding POF land management. According to Sukwika et al. (2018), family farmers predominantly determine whether their land would be maintained as POF or used for other agricultural activities including rice fields, or ponds.

The results showed that the management system in the three sites was entirely individual, both on small, medium, and large plots. Therefore, all decisions in managing POF land were primarily dependent on owners and POF performance was influenced by the behavior of farmers towards land management. While some managed their land casually, others adopted new knowledge and innovations.

Business orientation refers to the motive behind POF cultivation, whether for subsistence or commercial purposes, and the degree of subsistence and commercialization measures responsiveness to the market economy. Furthermore, the orientation of farmers in managing POFs varies. Most farmers were oriented towards meeting their daily needs (Achmad et al., 2022), while some perceived POF as a means to get savings for urgent needs. Sukadaryati et al., (2018) found that POF in Ciamis Regency was often treated as savings and harvested to fulfill personal needs or sold to address urgent financial obligations.

Commercial orientation was predominantly observed among farmers with significant land ownership. The planting of timber and fruit trees by several large landowners in Hujungtiwu village was targeted at making large profits.

Farmers with a commercial orientation tended to carry out more planned land management, from preparation to future marketing plans. Therefore, the performance of POF yielded good economic and ecological outcomes.

POF performance can also be influenced by the type and diversity of products consumed or marketed, which is a response to market needs. Regarding the type and diversity of products, farmers with small landholdings and intensive management tended to plant annual crops, with less than 50% timber. Farmers with medium and large land areas planted a mixture of annual crops and timber, while those having large land areas cultivated timber and fruit trees (MPTs). Crop diversification is one of the strategies to overcome narrow land tenure (Musdi et al., 2020). Furthermore, community culture as manifested in diverse cropping patterns also affected POF management, particularly in sustaining performance. This approach aimed to ensure that the use of forest resources provided benefits in a productive, sustainable, equitable, and efficient manner (Anen, 2017).

IV. CONCLUSION

There has been a lot of research on POF management in terms of participation, motivation, marketing, contribution, institutions, and policies, while research on POF performance is still limited. This study aimed to know POF traditional management by farmers, POF performance, and their influencing factors. This study concludes that knowledge concerning POF management was constantly developing, but not all farmers applied this knowledge in the production, processing, and marketing subsystems. In Kalijaya Village, where the condition of the POF is better, the POF management looks better than in the other village. Management practices were closely related to marital status, farming experience, and POF conditions such as POF land area, distance from home, number of land parcels, and income. The traditional management practices of farmers were reflected in POF performance. High POF performance ideally includes high POF productivity, sustainable POF management, equitable benefits of management rules, and efficient POF management costs. The POF in Kalijaya Village was included in the high-performance category, but the high elements of POF performance were only equitability, efficiency, and sustainability, while productivity was low. In contrast to Kalijaya Village, POF performance in Mekarjaya and Hujungtiwu Villages was moderate, with high elements of equitability and efficiency, low productivity, and moderate sustainability. The differences in the performance of the POFs in the three locations are related to differences in the socio-economic conditions and management conditions of the POFs. The different conditions of each element, in particular productivity and sustainability, show that although POF might not be optimal in terms of yield for significant economic contribution, its sustainability provides environmental benefits. This study has many limitations as it only looks at factors within POF farmers that influence POF management and performance. Further research into external factors such as institutions, stakeholder involvement, and policies that can influence the performance of POFs and promote increased productivity and the economic role of POFs can be explored in more depth.

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GOLDEN RATIO INTERPRETATION ON 150 FLOWERS: THE BASIC INFORMATION TO DEVELOP ECOTOURISM IN BOGOR, INDONESIA

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GOLDEN RATIO INTERPRETATION ON 150 FLOWERS: THE BASIC INFORMATION TO DEVELOP ECOTOURISM IN BOGOR, INDONESIA. The Aesthetic value is one of the factors in order to attract tourists to visit. Flowers are one form of tourist attraction that symbolizes beauty, flowers can be used as an object of interpretation for the development of ecotourism, especially in interpreting the meaning of the aesthetic value. Assessment of beauty can be measured by a number that is believed to have beauty, namely by using the golden ratio. Research has shown that the golden ratio actually exists in flowers. The knowledge of the golden ratio of flowers, in addition to increasing tourist attraction, can also be used as an interpretation for tourists because the aesthetic value is very important to the human relationship with nature, and the motivation to protect it. Golden ratio analysis was performed on 150 flowers. A flower is said to have a golden ratio if the ratio results in a comparison of flower morphology producing a number of 1.618 or close to that number. The discovery of the golden ratio in all flowers shows that flowers are creations that have aesthetic value so visitors are expected to be able to interpret the importance of the value of beauty in living things for their tour experience.

Keywords: Aesthetic value, ecotourism interpretation, flower, golden ratio

INTERPRETASI RASIO EMAS PADA 150 BUNGA: INFORMASI DASAR UNTUK MENGEMBANGKAN EKOWISATA DI BOGOR, INDONESIA. Nilai estetika merupakan salah satu faktor untuk menarik minat wisatawan untuk berkunjung. Bunga merupakan salah satu bentuk daya tarik wisata yang melambangkan keindahan, bunga dapat dijadikan objek interpretasi untuk pengembangan ekowisata, khususnya dalam memaknai nilai estetika. Penilaian kecantikan dapat diukur dengan angka yang diyakini memiliki nilai keindahan yaitu dengan menggunakan rasio emas. Penelitian telah menunjukkan bahwa rasio emas benar-benar ada pada bunga. Pengetahuan rasio emas bunga selain untuk meningkatkan daya tarik wisata juga dapat dijadikan sebagai interpretasi bagi wisatawan karena nilai estetika sangat penting bagi hubungan manusia dengan alam, serta motivasi untuk menjaganya. Analisis rasio emas dilakukan pada 150 bunga. Suatu bunga dikatakan memiliki rasio emas jika rasio hasil perbandingan morfologi bunga menghasilkan angka 1,618 atau mendekati angka tersebut. Ditemukannya rasio emas pada semua bunga menunjukkan bahwa bunga merupakan ciptaan yang memiliki nilai estetika, sehingga pengunjung diharapkan mampu memaknai pentingnya nilai keindahan pada makhluk hidup untuk pengalaman berwisata mereka.

Kata kunci: Bunga, interpretasi ekowisata, nilai estetika, rasio emas

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I. INTRODUCTION

The Aesthetic value is one of the factors in order to attract tourists to visit. Aesthetic values in the field of tourism cannot be separated from one another. In terms of aesthetic connotations, tourism aesthetics mainly refers to tourists' personal experiences, appreciation and creation of beauty in the travel process (Li, 2017). Aesthetic value is what people "feel" about a particular landscape, and aesthetic value can influence tourists' perceptions of a destination and their sightseeing experience to other parts of the trip and then to other parts of the destination (Wang et al., 2008). Flowers are one form of tourist attraction that symbolizes beauty (Chan, 2015), or jewelry (Hůla & Flegr, 2016). Flowers have become something interesting to study, both by definition (Nadot & Dodinet 2016), studying the morphology of various flower species (Hamim et al., 2019) to their benefits for various purposes of human life (Chen et al., 2020; Jauker et al., 2012). Based on these matters, flowers can be used as an object of interpretation for the development of ecotourism, especially in interpreting the meaning of the aesthetic value.

Assessment of beauty can be measured by a number that is believed to have beauty, namely by using the golden ratio (Iosa, 2018). This ratio is believed to be the divine ratio or golden number (Kissinger, 2012; Sharif, 2014). The golden ratio is the ratio between the parts or dimensions of one element. In other words, for a line, the ratio must fall between the two halves. The result of this ratio is 1.618 (Baiz & Khoshnaw, 2017; Ching, 2014). Based on the etymology of the word symmetry, as well as on specific examples and theories of beauty, golden ratio can also characterize symmetrical forms (Prokopakis et al., 2013). This ratio has been widely used in the fields of architecture (Agustin & Utomo, 2018; Ali & Prasetia, 2021; Astrini et al., 2015), art (Omotehinwa, 2013; Thapa & Thapa, 2018; Yulius, 2018), even in the forestry sector (Zelić, 2006).

Research has shown that the golden ratio actually exists in flowers. When observing sunflower seeds, a rotation will be produced which contains Fibonacci numbers (Naylor, 2002). Furthermore, many flowers have petal arrangements that correspond to Fibonacci numbers. Some have single or multiple lobes. Three petals are more common, as in lilies and irises. Some have 5 petals, such as buttercup, wild rose, larkspur, and columbine. Some have 8, 13, 21, 34, 55 or even 89 petals. All of these numbers are sequential Fibonacci numbers (Akhtaruzzaman & Shafie, 2011; Koshy, 2018; Omotehinwa, 2013).

The knowledge of the golden ratio of flowers, in addition to increasing tourist attraction, can also be used as an interpretation for tourist areas as well as interesting teaching materials for tourists and flower lovers in Indonesia. It is also important that the aesthetic experience of biodiversity is the act of appreciating and experiencing beauty through observing a species, assemblage of species or ecosystem. The aesthetic experience is of course very important to the human relationship with nature, and the motivation to protect it (Langlois et al., 2022; Tribot et al., 2019).

II. MATERIAL AND METHODS

This research was conducted in Bogor City, Bogor Regency to include Cianjur Regency with records that tend to be close to the Bogor area. The specific research locations are the Bogor Botanical Gardens, Cibodas Botanical Gardens, Research Center for Medicinal and Aromatic Plants (Balittro), Ornamental Plant Research Center (Balithi), Taman Bunga Nusantara, and locations such as roads and yards where there are flowers. The criteria for choosing a location are a location that has quite a large collection of flowers based on the initial survey data. The choice of sites increased as the research progressed until a total of 150 flowers could be filled.

A. Methods

The research data collected includeds primary and secondary data. The primary data in this study was the use of the golden ratio in flowers obtained through the documentation on the front view or/and side view of the flower surface. These data were obtained from the research locations. Secondary data in this study included flower taxonomy as material for categorizing flowers into families of each flower. The data were obtained from the plant encyclopedia. Special applications for identifying plants were used when collecting data.

The method used was field observation by observing, measuring, and documenting flowers in the case study areas. Data obtained through field observations, namely the size of the flower including the size of the petals, crown, stalk, and overall height of the flower. The tool used to obtain flower sizes was a caliper, while images of flowers were obtained using a camera.

There were 150 flowers to be selected in this study. The list of flowers was categorized by the family of the flower (Table 1).

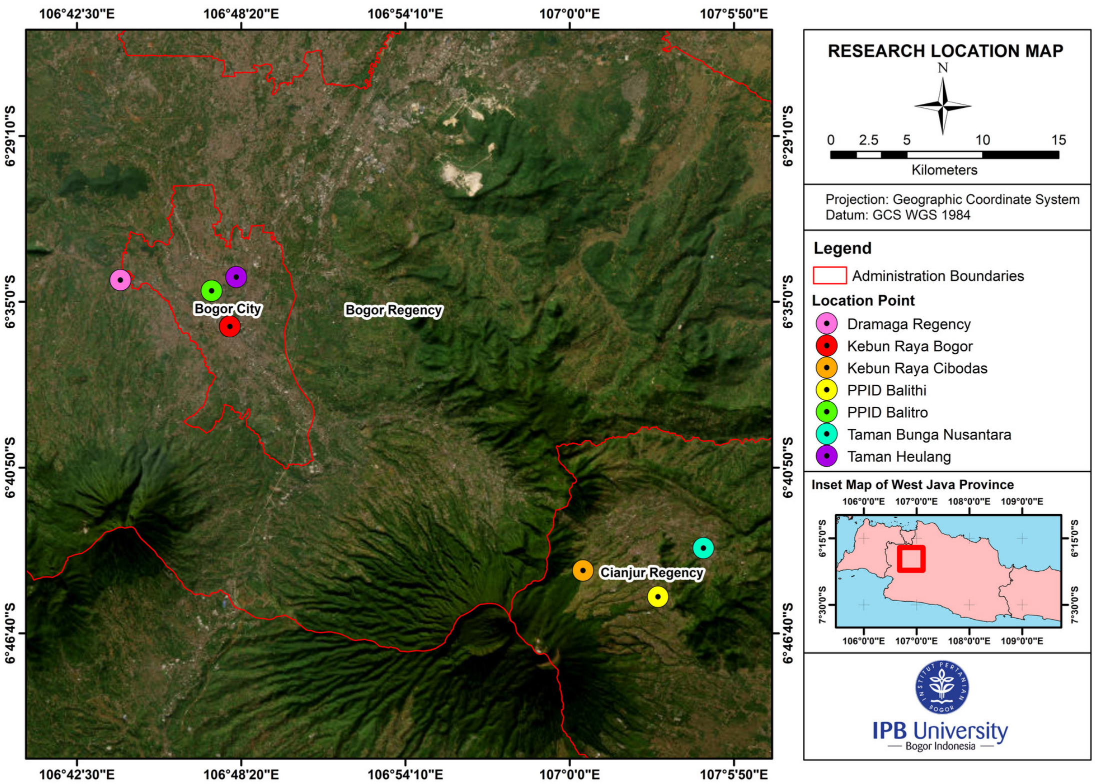

Figure 1. Research location

Table 1. List of 150 flowers based on their family

No.	Family	Species
	Acanthaceae	Bengal clockvine (*Thunbergia grandiflora*)*, Chinese violet (*Asystasia gangetica*), firecracker flower (*Crossandra infundibuliformis*), golden shrimp plant (*Pachystachys lutea*)*, green chiretta (*Andrographis paniculata*), Mexican petunia (*Ruellia simplex*), Mexican shrimp plant (*Justicia brandegeeana*), mysore trumpetvine (*Thunbergia mysorensis*), Philippine violet (*Barleria cristata*), yellow-vein eranthemum (*Pseuderanthemum maculatum*)

Table 1. Continued

No.	Family	Species
	Agavaceae	Tuberose flower (*Polianthes tuberosa*)*
	Alismataceae	Water jasmine (*Echinodorus palaefolius*)
	Amaranthaceae	Cockscomb flower (*Celosia argentea*), globe amaranth (*Gomphrena globosa*)*
	Amaryllidaceae	African lily (*Agapanthus praecox*), Amazon lily (*Eucharis amazonica*)*, beach spider lily (*Hymenocallis littoralis*), *Eucrosia bicolor*, striped barbados lily (*Hippeastrum striatum*), white rain lily (*Zephyranthes candida*)
	Annonaceae	Ylang-ylang (*Cananga odorata*)*
	Apocynaceae	Frangipani flower (*Plumeria rubra*), kopsia (*Kopsia arborea*), Madagascar periwinkle (*Catharanthus roseus*), pinwheel flower (*Tabernaemontana divaricata*), purple allamanda (*Allamanda blanchetii*), sea mango (*Cerbera manghas*)*, yellow allamanda (*Allamanda cathartica*)
	Araceae	Flamingo flower (*Anthurium andraeanum*), peace lily (*Spathiphyllum wallisii*)
	Asteraceae	Barberton daisy (*Gerbera jamesonii*), cobblers pegs (*Bidens pilosa*), dahlia (*Dahlia* pinnata), elegant zinnia (*Zinnia elegans*), gold medallion (*Melampodium divaricatum*), Indian chrysanthemum (*Chrysanthemum indicum*), king's salad (*Cosmos caudatus*)*, marigold (*Tagetes erecta*), Mexican fleabane (*Erigeron karvinskianus*), Mexican tournesol (*Tithonia diversifolia*)*, wedelia (*Sphagneticola trilobata*)*
	Balsaminaceae	Bussy lizzy (*Impatiens walleriana*)*, garden balsam (*Impatiens balsamina*)*, New Guinea impatiens (*Impatiens hawkeri*)*
	Begoniaceae	Polka dot begonia (*Begonia maculata*), wax begonia (*Begonia cucullata*)
	Bignoniaceae	African tulip tree (*Spathodea campanulata*)*, rosy trumpet tree (*Tabebuia rosea*)*, yellow trumpet bush (*Tecoma stans*)*
	Caesalpiniaceae	Candle bush (*Senna alata*)*
	Campanulaceae	Star of bethlehem (*Hippobroma longiflora*)
	Cannaceae	African arrowroot (*Canna indica*)
	Caricaeae	Papaya (*Carica papaya*)
	Commelinaceae	*Murdannia nudiflora*, oyster plant (*Tradescantia spathace*a)
	Convolvulaceae	Cairo morning glory (*Ipomoea cairina*)*, morning glory (*Ipomoea indica*)*, sweet potato (*Ipomoea batatas*), water spinach (*Ipomoea aquatica*)
	Costaceae	Crepe ginger (*Costus speciosus*)*
	Cucurbitaceae	Cucumber (*Cucumis sativus*)
	Dilleniaceae	Elephant apple (*Dillenia philippinensis*)*
	Ericaceae	Azalea (*Rhododendron indicum*), Flame Azalea (*Rhododendron calendulaceum*)
	Euphorbiaceae	Coral plant (*Jatropha multifida*), crown of thorns (*Euphorbia milii*)*, gout plant (*Jatropha podagrica*), Peregrina (*Jatropha integerrima*),
	Fabaceae	Asian pigeonwings (*Clitoria ternatea*)*, butterfly tree (*Bauhinia purpurea*)*, *Calliandra surinamensis**, jade vine (*Strongylodon macrobotrys*), pinto peanut (*Arachis pintoi*), peacock flower (*Caesalpinia pulcherrima*), vegetable hummingbird (*Sesbania grandiflora*)*
	Gesneriaceae	Copper leaf (*Chrysothemis pulchella*), *Seemannia sylvatica*
	Iridaceae	African iris (*Dietes bicolor*), blue star (*Aristea ecklonii*), montbretia (*Crocosmia crocosmiiflora*), walking iris (*Trimezia longifolia*), water iris (*Neomarica gracil*is)
	Lamiaceae	Bleeding glory-bower (*Clerodendrum thomsoniae*)*, cat's whiskers (*Orthosiphon aristatus*)*, Chinese hat plant (*Holmskioldia sanguinea*), great basil (*Ocimum basilicum*), Coleus (*Coleus scutellarioides*), Lavender (*Lavandula angustifolia*), Mealy Sage (*Salvia farinacea*), scarlet sage (*Salvia splendens*), white teak (*Gmelina arborea*)*
	Liliaceae	Yellow daylily (*Hemerocallis lilioasphodelus*)
	Linderniaceae	Wishbone flower (*Torenia fournieri*)
	Lythraceae	Taiwan beauty (*Cuphea hyssopifolia*), Thai crape myrtle (*Lagerstroemia floribunda*)*

Table 1. Continued

No.	Family	Species
	Magnoliaceae	White champaca (*Magnolia alba*)*
	Malvaceae	Caesar weed (*Urena lobata*), Chinese hibiscus (*Hibiscus rosa sinensis*), Chinese-lantern (*Abutilon pictum*), guest tree (*Kleinhovia hospita*), sleeping hibiscus (*Malvaviscus arboreus*)
	Melastomataceae	*Heterocentron subtriplinervium,* Malabar melastoma (*Melastoma malabathricum*), princess flower (*Tibouchina urvilleana*)
	Nyctaginaceae	Great bougainvillea (*Bougainvillea spectabilis*)*
	Nymphaeaceae	Lotus (*Nymphaea lotus*), *Nymphaea nouchali var careulea*,
	Ochnaceae	Mickey mouse flower (*Ochna serrulata*)
	Oleoaceae	Common jasmine (*Jasminum officinale*), jasmine (*Jasminum sambac*), night blooming jasmine (*Nyctanthes arbor-tristis*)*
	Orchidaceae	Boat orchid (*Cymbidium sinense*), hooded orchid (*Dendrobium aphyllum*), moon orchid (*Phalaenopsis amabilis*)*, oncidium sharry baby, Philippine ground orchid (*Spathoglottis plicata*)*, scorpion orchid (*Arachnis flos-aeris*), spider orchid (*Brassia sp.*), venus slipper (*Paphiopedilum acmodontum*)
	Oxalidaceae	Bilimbi (*Averrhoa bilimbi*)
	Passifloraceae	Ramgoat dashalong (*Turnera ulmifolia*)
	Plumbaginaceae	Ceylon leadwort (*Plumbago zeylanica*)*
	Polygonaceae	Coral vine (*Antigonon leptopus*)*
	Pontederiaceae	Pickerelweed (*Pontederia cordata*)
	Punicaceae	Pomegranate (*Punica granatum*)
	Rosaceae	Red rose (*Rosa kordesii*), white rose (*Rosa alba*)
	Rubiaceae	Ashanti blood (*Mussaenda erythrophylla*), cape jasmine (*Gardenia jasminoides*)*, Egyptian starcluster (*Pentas lanceolata*), Indian mulberry (*Morinda citrifolia*)*, *Pavetta indica*, West Indian jasmine (*Ixora javanica*)
	Rutaceae	Orange jasmine (*Murraya paniculata*)*
	Saururaceae	Fish leaf (*Houttuynia cordata*)*
	Scrophulariaceae	Fountain bush (*Russelia equisetiformis*)*
	Solanaceae	Brazil's white angel trumpet (*Brugmansia suaveolens*)*, *Brunfelsia uniflora**, chili (*Capsicum frutescens*), petunia (*Petunia atkinsiana*), potato (*Solanum tuberosu*m)
	Talinaceae	Fame Flower (*Talinum paniculatum*)
	Verbanaceae	Blue fountain bush (*Clerodendrum serratum*), blue porterweed (*Stachytarpheta jamaicensis*), *Clerodendrum calamitosum*, common lantana (*Lantana camara*), golden dewdrop (*Duranta erecta*), purple wreath (*Petrea volubilis*)
	Zingiberaceae	Aromatic ginger (*Kaempferia galanga*), shell ginger (*Alpinia zerumbet*), tumeric (*Curcuma domestica*)

Note: *) Flowers from the forest

B. Analysis

The data that has been obtained was described digitally to facilitate the analysis of the proportion of the golden ratio. Calculation of the golden ratio was done by first looking at the morphology of each flower. Analysis can be done by comparing the length of the flower to the stem, and the overall size of the flower. The documentation results that have been obtained from the object were then compared with the golden ratio formula (See Figure 2).

Flowers that are considered to contain the golden ratio, that is, if the height, length, width, and area of the object are divided then produce numbers, namely 1.618 or close to that number. If there is a ratio that has a number very far

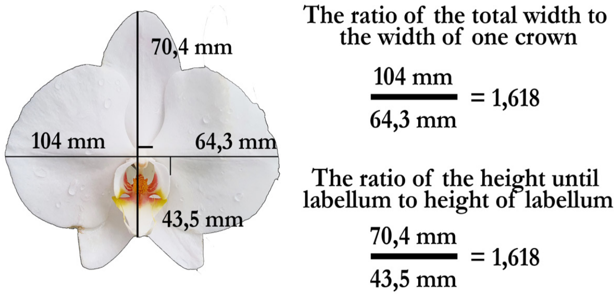

Figure 2. An example of calculating the golden ratio in flowers

from 1.618, then the flower does not contain the golden ratio in it. A number is said to be the golden ratio if the ratio of numbers (for example a+b) divided by a larger number (b) is the same as the result of the large number divided by a smaller number (b/a) (Benjafield & Davis, 1978; Green, 1995). If the numbers obtained are far from the numbers 1.618 and 0.618, then it can be said that the flower that has been measured does not contain the golden ratio. The applications used in this study are Adobe Photoshop and Image J. The measurement results are then processed using the Adobe Photoshop application with a line forming tool used to make comparison lines to obtain the existence of the golden ratio in the flower that has been measured. The ImageJ application is used to get results in the form of area comparisons. The golden ratio has a close relationship with Fibonacci numbers (Fn = Fn-1+Fn-2) (Chasnov, 2016; Livio, 2002), so one example of the ratio in the area can be found in the total area of a flower (the majority of 5 petals) with an area of 3 petals.

III. RESULT AND DISCUSSION

1. Golden Ratio on Flower

Based on the table list of flowers (Table 1), the family with the most flowers in this study is the Asteraceae family, totaling 11 species. Followed by the Acanthaceae and Lamiaceae families with 9 species, Orchidaceae with 8 species, and so on. The analysis revealed that most flowers exhibit the golden ratio or values that closely match it.. The difference in the values on the flowers has various factors. Mainly, flowers that have a larger size will get a golden ratio of 1.618 compared to smaller flowers. Further, the golden ratio number (1.618) has three decimal places, while the research measurement tool only produced one decimal point. Weaknesses in the tool made the obtained value only close to 1.618. There were flowers that contain one golden ratio, two golden ratios, three golden ratios, and four golden ratios. For example, the moon orchid contains two golden ratios, the first ratio between the total width of petals with the width of one petal, the second ratio between the total height and the height of the labellum (See Figure 2). The following is a graph of the number of golden ratios of the studied flowers.

The findings showed that 66.7% or 100 flowers contain 2 golden ratios in them. There were variations in the golden ratios of the flowers, however, each flower was noted to have golden ratio in the ratio of area and the ratio of distance. The distance ratio, which is the ratio between the total length and the length of the crown, is also the ratio of the length and width of the flower. Flowers with three golden ratios were also noticed, with a proportion of 22.7% or 34 flowers. Flowers with only one golden ratio were found with a proportion of 8.7%. Moreover, only one flower (wishbone flower) or 0.7% was noted with four golden ratios with a proportion of 0.7%.

The golden ratio are influenced by various flower morphologies, therefore the obtained results were vary. The analysis found 12

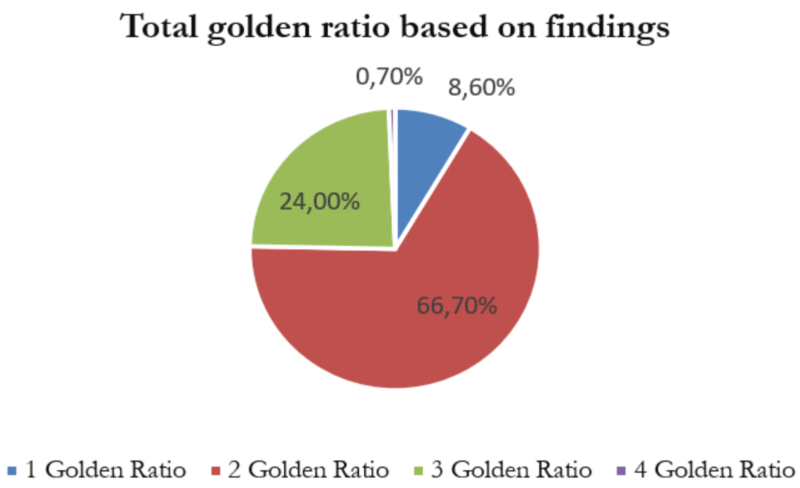

Figure 3. Total golden ratio based on findings on flower

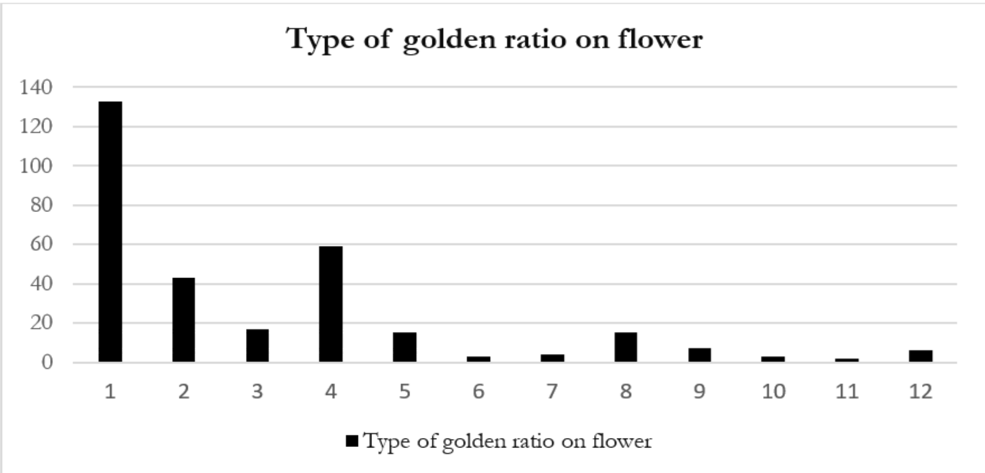

Figure 4. Type of golden ratio on flower

comparisons of the golden ratio in the flowers. The golden ratio that most flowers have is the ratio of area (type 1). Type 2 is the golden ratio between the length and width of the flower, type 3 is the ratio of the total height of the flower to the height of the crown to the stalk or other parts, type 4 is the ratio of the diameter/ length/width of the total flower to the length/ height of the crown of one flower, type 5 is the ratio of the length to the tube with the length of one flower petal, type 6 is the ratio of the part of the flower that has a split, type 7 is the ratio of the long and short distances, type 8 is the ratio of the flower pattern, type 9 is the ratio of the height and width of the flower, type 10 is the ratio of the slanted side and the base, type 11 is the ratio of the circumference, and finally type 12 is the ratio of 2 petals with different size. The following is a graph of the comparison of the golden ratios found in this study and the amount of flowers from each type (see Figure 4). The list of flowers classified based on the type of golden ratio found is presented in Table 2.

Area comparison was the result of the golden ratio that was most often found in this study. The results of the analysis using the ImageJ application showed that a comparison of the total area with the area of various parts of the flower can produce the golden ratio number

Table 2. List of flowers by type of the golden ratio

No.	Type of golden ratio	Species	Interpretation message for visitors
	The ratio of area	133 flowers except for the african tulip tree, barberton daisy, bussy lizzy, *Calliandra surinamensis*, crown of thorns, flamingo flower, lavender, lotus, marigold, mealy sage, mickey mouse flower, mysore trumpetvine, *Nymphaea nouchali var. caerulea*, pinto peanut, shell ginger, turmeric, West Indian jasmine	Findings on area comparisons are generally found in the comparison between the total flower crown strands (5 strands) versus 3 flower crown strands. This shows that there are Fibonacci numbers in flowers. The number of strands in each flower gives a flower a beautiful value
	The ratio between the length and width of the flower	African arrowroot, African tulip tree, aromatic ginger, azalea, bleeding glory-bower, blue fountain bush, blue porterweed, cape jasmine, Chinese hibiscus, Chinese violet, *Clerodendrum calamitosum,* cobblers pegs, coral vine, crepe ginger, Egyptian starcluster, fame flower, flame azalea, flamingo flower, frangipani flower, green chiretta, gout plant, jasmine, king's salad,, Malabar melastoma, *Murdannia nudiflora*, peace lily, peregrina, Philippines ground orchid, pinwheel flower, princess flower, purple wreath, ramgoat dashalong, scorpion orchid, sea mango, *Seemannia sylvatica,* striped barbados lily, Thai crape myrtle, venus slipper, walking iris, West Indian jasmine, white rain lily, yellow-vein eranthemum, yellow trumpet bush	The comparison of flower length and width in this finding can be in the form of the total flower size or flower parts such as flower petals. This finding shows that the length and width of some flower species are proportional. This balanced part creates aesthetic value.
	The ratio of the total height of the flower to the height of the petals to the stalk or other parts	Candle bush, cat's whiskers, cockscomb flower, *Eucrosia bicolor*, *Heterocentron subtriplinervium*, golden shrimp plant, guest tree, lavender, Mexican shrimp plant, moon orchid, Mysore trumpetvine, pinto peanut, peacock flower, shell ginger, scarlet sage, sleeping hibscus, tuberose flower	The golden ratio in the ratio of flower height shows that the flower grows while showing its beauty value.
	The ratio between total length and one petal	*Abutilon pictum*, African lily, Amazon lily, aromatic ginger, ashanti blood, Bengal clockvine, bleeding glory-bower, blue fountain bush, blue star, *Brunfelsia uniflora*, bussy lizzy, caesar weed, Cairo morning glory, cape jasmine, chili, common lantana, coral plant, crepe ginger, crown of thorns, cucumber, dahlia, elephant apple, flame azalea, fountain bush, golden dewdrop, globe amaranth, great bougainvillea, guest tree, *Heterocentron subtriplinervium*, *Houttuynia cordata*, Indian murberry, king's salad, lotus, marigold, mealy sage, Mexican petunia, mickey mouse flower, moon orchid, morning glory, New Guinea impatiens, night blooming jasmine, oncidium sharry baby, orange jasmine, papaya, petunia, pickerelweed, Philippine violet, purple wreath, red rose, rosy trumpet tree, taiwan beauty, tuberose flower, water jasmine, wax begonia, white champaca, white rose, white teak, wishbone	This finding shows that the size of each part of the flower, such as the petals, has a length that makes the flower look beautiful. If the flower part is longer or shorter it may not make the flower look beautiful.

No.	Type of golden ratio	Species	Interpretation message for visitors
	The ratio between the length of the tube with the length of one flower petal	Barberton daisy, blue porterweed, Brazil's white trumpet angel, cobblers pegs, elegant zinnia, gold medallion, Indian chrysanthemum, Mexican fleabane, Mexican tournesol, pomegrante, potato, purple allamanda, sweet potato, wedelia, yellow allamanda	This comparison is generally found in the Asteraceae family, but there are several from other families. The part called the tube is the discus, which is the part of the flower that consists of small flowers that contain nectar which is useful for insects. These findings show that the tube/circle-shaped part, apart from providing aesthetic value, also provides benefits, especially for insects.
	The ratio of the part of the flower that has a split	Bussy lizzy, garden balsam, New Guinea impatiens	This finding shows the uniqueness of the Balsaminaceae family. The heart shape found on the flower petals is the beauty value of this family.
	The ratio of the long and short distances	Ceylon leadwort, cymbidium orchid, star of bethlehem, water spinach	Flowers can look beautiful because they have a proportional distance between the flower parts. In this case, that is the distance between the two upper flower crowns and the distance between the lower flower crowns.
	The ratio of the flowers pattern	Aromatic ginger, Asian pigeonwings, beach spider lily, bilimbi, *Calliandra surinamensis*, coleus, copper leaf, *Dietes bicolor*, great basil, montbretia, *Pavetta indica*, pickerelweed, striped barbados lily, water iris, wishbone	The patterns on the flowers really give beauty to each flower. However, if the pattern placement is not as it currently appears, it could result in something that is not beautiful. The finding of the golden ratio in the patterns shows that the patterns in the flowers are placed in a position that can provide aesthetic value.
	The ratio of the height and width	*Abutilon pictum*, *Houttuynia cordata*, *Nymphaea nouchali var careulea*, polka dot begonia, vegetable hummingbird	The beauty of flowers can be found in various dimensions. This finding shows that the species in this discovery have a point of beauty when viewed in this dimension.
	The ratio of the slanted side and the base	Common jasmine, kopsia, *Pavetta indica*	The flower species in this discovery have smaller flower petals compared to other species. The ratio of the slanted side and the base is a finding that shows that each petal has a growth that contains beauty because the petals expand in the right direction, making the flower pleasing to the eye.
	The ratio of the circumference	Lavender, Mysore trumpetvine	This finding shows that the outer part of the flower surrounds the inner part of the flower, creating beautiful proportions in these two species.
	The ratio of the 2 petals with different sizes	Butterfly flower, jade vine, lotus, Philippine ground orchid, turmeric, yellow daylily	These findings suggest that different sizes can provide aesthetic value. The beauty of flowers is not only found in flowers that have similar sizes, but different sizes can also provide beauty value.

for all the studied flowers. There were 133 flower counts showed the golden ratio in area comparison. Generally, the area comparison can be found in flowers that have 5 petals than in 3 petals flowers (See Figure 5). The results of this comparison show that there is a relationship between the golden ratio and the Fibonacci numbers because 3 and 5 are part of the Fibonacci numbers. To further strengthen the relationship between the two, this fact was also found in flowers with 8 petals like white jasmine and flowers with 13 strands like wedelia flowers (see Figure 6).

The two flowers jasmine flower has 5 flower petals and wedelia flower has 8 flower petals. The numbers 5, 8, and 13 are part of the Fibonacci numbers, so these findings show that there is a very close relationship between the golden ratio and the Fibonacci numbers as shown in the ratio of flower area (Banerjee & Sinha, 2019). Although many golden ratios were found in area ratios related to Fibonacci numbers, however, flowers with six petals and various strand numbers may exhibit area ratios that align with the golden ratio. For example, yellow-vein eranthemum, ylang, and flowers from the Amaryllidaceae family are examples of flowers with 4, 9, and 6 petals, that had the golden ratio in the area ratio of these flowers (Figure 7).

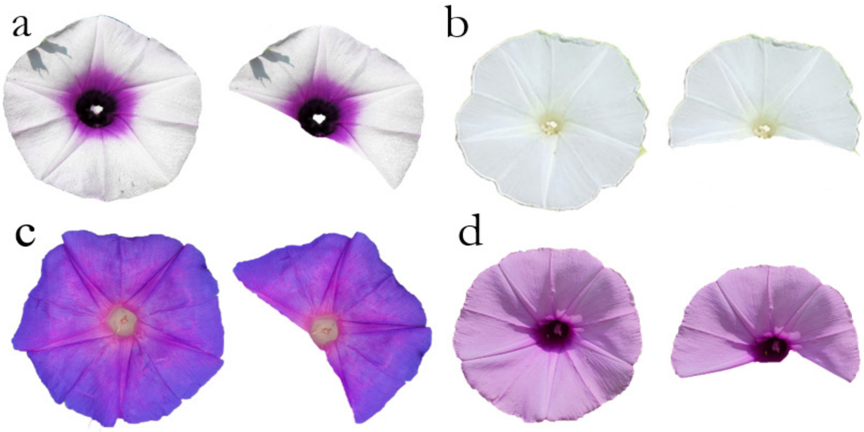

Figure 5. The golden ratio on the flower area of the *Convolvulaceae* family. (a) sweet potato, (b) water spinach, (c) morning glory, and (d) Cairo morning glory

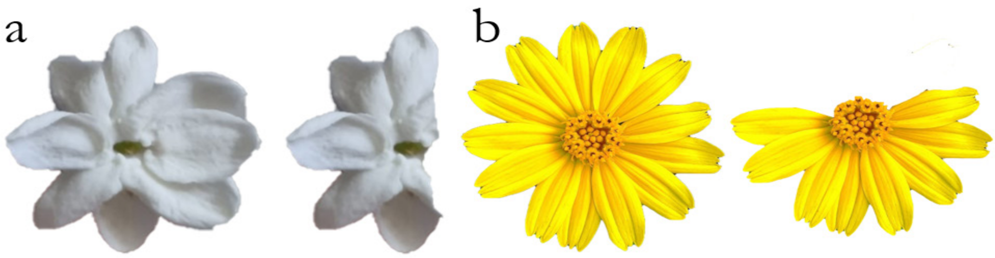

Figure 6. The golden ratio on the flowers area of (a) jasmine and (b) wedelia flower

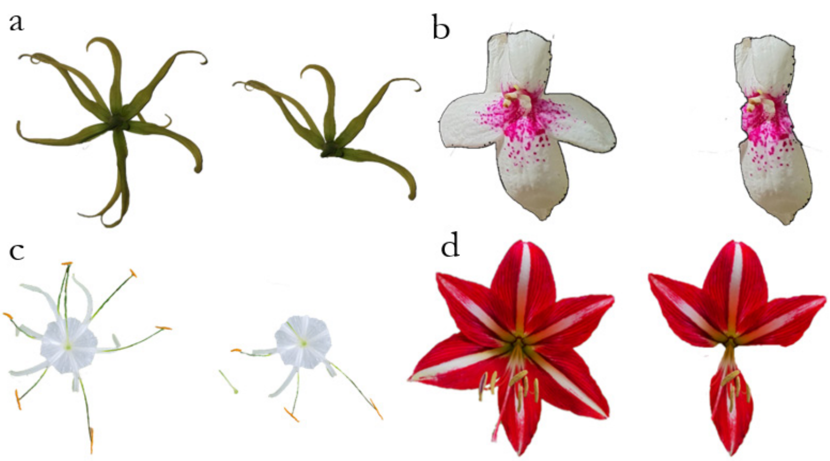

Figure 7. The golden ratio on flowers with non-Fibonacci number of petals (a) ylang-ylang, (b) yellow-vein eranthemum, (c) beach spider lily, and (d) striped barbados lily

The golden ratio in the ratio between the length and width of flowers was found in 38 flowers, which was the third highest golden ratio found in this study. The flowers with the golden ratio in the ratio of length to width were frangipani flower, pinwheel flower, princess flower, and Israel grass flowers (see Figure 8).

Ratios of the length and width of the flower can be found in the petals and the whole flower as in the Israel grass flower. The length of the flower petals is the length of the flower pistil. The Frangipani flower has a size of 26.1 mm /16.2 mm, so the number 1.611 is obtained. The pinwhell flower has a size of 18.2 mm / 11.3 mm then the number 1.610 is obtained. Princess flower has a larger size than the previous two flowers with a size of 32.8 mm / 20.3 mm and the number 1.615 is obtained from this comparison. Chinese violet flower has a small size with a size of 20.7 mm / 12.8 mm, the number 1.617 is obtained from the ratio of the total length and width of the flower.

The ratio of the total height of the flower with the height of the crown to the stalk or other parts was found in the flowers of the cockscomb, golden shrimp plant, Mexican shrimp, and candle bush. Other parts can be interpreted as when the stem, flower petals, or leaves appear (see Figure 9).

Cockscomb has a total height of 412.4 mm and a height of 254.9 mm until the leaves appear. The results of the comparison produce the number 1.618. Golden shrimp flower has a total height of 103.9 mm and a height of 64.2

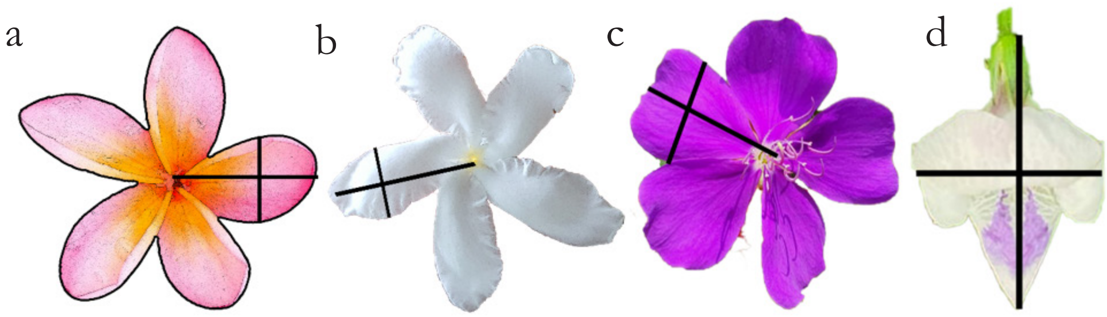

Figure 8. The golden ratio on (a) frangipani flower, (b) pinwhell flower, (c) princess flower, and (d) Israel grass flower

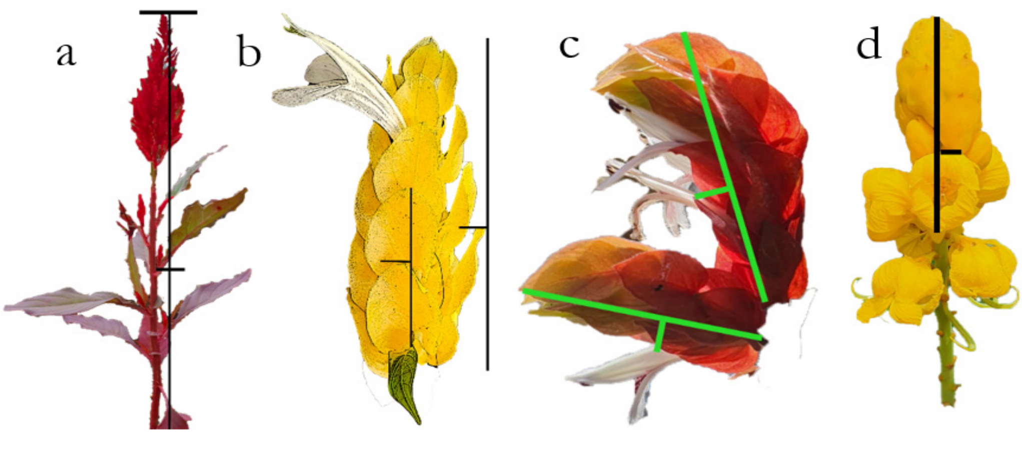

Figure 9. Golden ratio on height. (a) cockscomb, (b) golden shrimp plant, (c) Mexican shrimp, and (d) candle bush

Figure 10. The golden ratio between total length and one petal. (a) Papaya, (b) Indian mulberry, (c) Indian blooming jasmine, (d) lotus

Figure 11. The golden ratio between the length of the tube and the length of one petal. (a) Elegant zinnia, (b) Mexican tournesol, (c) yellow allamanda, (d) Brazil's white angel trumpet

mm when the yellow leaves emerge, giving a golden ratio of 1.618. As for the comparison of the total height of 2 leaves with 1 leaf with a size of 36.8 mm/22.7 mm, the number is 1.621. In the Mexican shrimp flower, the yield ratio is similar to that of the wax flower, but the flower crown is in the middle, which is different from the wax flower, which is at the top. The comparison of these heights is 54.2 mm/33.5 mm and 51.6 mm/31.9 mm, respectively, thus the golden ratio is 1.618. Candle bush has a height at the top of 80.9 mm which compares to the height of the candle-shaped section of 50 mm. The number 1.618 was obtained in this comparison. The results for the four flowers show the number 1.618 because they have a large size which makes the comparison numbers even bigger. The larger the size obtained, the easier it will be to obtain the golden ratio number when compared to smaller flowers.

The ratio of total flower diameter/length/ width to the length/height of one petal is the second highest golden ratio found in this study. This measurement is put into a different category from the ratio of the total height of the flower because in this comparison the size of the flower is taken from the top view of the flower. Examples of this comparison can be found in the previous flowers, namely the morning glory flower and the kates sweet potato flower. Other examples of this comparison can be found in the papaya flower, Indian mulberry flower, night blooming jasmine, and lotus.

The ratio of diameters can be seen in Figure 5. namely morning glory and sweet potato. Furthermore, the ratio of the total length to the length of one flower corolla was found in papaya, Indian mulberry, night blooming jasmine, and lotus flowers. The papaya flower has a golden ratio of 19.3 mm / 11.9 mm, which is 1.621. Indian mullbery flowers have a total length of 9.7 mm and the length of one crown is 6, thus the golden ratio is 1.616. The night blooming jasmine flower has a total length of 24 and the length of a crown of 24.5 mm thus the ratio value is quite far from the golden ratio's. The difference with the previous type is in this ratio, the length of one strand is taken. The night blooming jasmine flower has a line of intersection between its flower petals. If the length like the previous flower is taken then then value of the golden ratio or close to that of the golden ratio will not be obtained. However, when measured up to the intersection line, the sizes of 14.8 and 15.2 mm were used, so when compared, numbers that are close to the golden ratio would be obtained, namely 1.621 and 1.612. The lotus flower with a size of 55.7 mm / 34.5 mm when viewed from above will produce a golden ratio of 1.614. In this comparison, it can be found that the pistil is an important component of creating the golden ratio in flowers.

The ratio of the length to the tube with the length of one flower crown is a comparison that is almost the same as the ratio of the total length to one flower crown, the difference is in the length used. The length in this comparison is the distance from the tip of the crown to the end of the central part of the flower which resembles a tube. Of course, the flowers that fall into this category are flowers that have a tube in the middle such as flowers from the Asteraceae family, e.g. the elegant zinnia and Mexican tournesol. Sweet potato (see Figure 5) has a golden ratio in this ratio type, besides yellow allamanda and Brazil's white angel trumpet flowers.

Figure 13 shows the tube in the flower can also be interpreted as the middle part of the flower, which can be a small flower, stamens, pistils, or whole tube. Elegant zinnia has yellow flowers that resemble rings so that they form a circle in the center of the flower (Gulton et al., 2013). Mexican tournesol flowers have a tube containing pistils and stamens, while the yellow allamanda flower and Brazil's white angel trumpet flower have a complete tube shape. The elegant zinnia flower has a ratio of 31.4 mm/19.4 mm, resulting in a golden ratio of 1.618. Kipait with a size of 75 mm/46.4 mm scored 1.616, yellow allamanda flowers with a size of 66.9 mm/41.3 mm scored 1.619 and Brazil's white angel trumpet with a size of 77.2 mm/47.7 mm scored the golden ratio of 1.618.

Figure 12. The golden ratio of the *Balsaminaceae* family

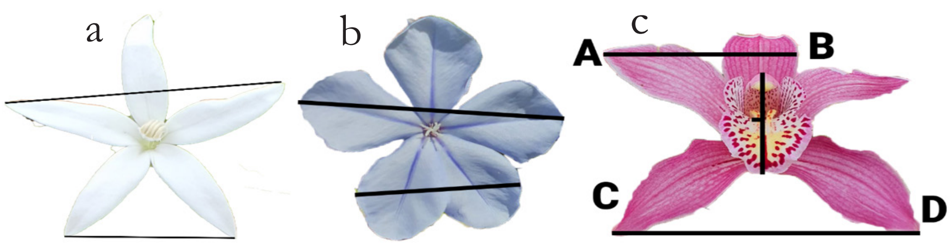

Figure 13. The golden ratio on two different lengths. (a) star of bethlehem, (b) ceylon leadwort, (c) cymbidium orchid

The next golden ratio is the golden ratio found in the *Balsaminaceae* family, namely the ratio of the flower halves. The flower morphology of the *Balsaminaceae* family has a split that resembles a wing and consists of 5 flower petals (Yilin, 2001).

Based on the morphology of the three flowers, Impatiens balsamina has a different morphology from Impatiens hawkeri and Impatiens walleriana. The results also show that Impatiens balsamina only has one golden ratio. Impatiens baslamina flower with a size of 15.3 mm/9.5 mm thus has a ratio of 1.610. Impatiens hawkeri flower has a cleavage size of 21 mm/12.9 mm, thus the ratio is 1.627. Impatiens walleriana flower with a slit size of 12.7 mm/7.9 mm gives a ratio of 1.607.

The ratio of the long and short distances is the distance measured from the end of one crown to the other end of the crown (Figure 13). There are only 4 flowers in this comparison, namely Water Spinach (see Figure 5), star of bethlehem, ceylon leadwort, and cymbidium orchid.

The results of measuring the length of the distance between the crowns of the stars of the bethlehem flower were 31.4 mm at the distance of the upper crown and 19.4 mm at the distance of the lower crowns/base. The result of the comparison is the golden ratio of 1.618. Ceylon leadwort has a distance between the upper crowns of 26.9 mm and a distance between the lower crowns/base of 16.6 mm, thus the ratio is 1.620. Cymbidium flowers have a longer distance between the lower crowns which is marked with CD and a shorter distance marked as line AB (Figure 15). The length of CD is 80.1 mm compared to 49.5 mm for the length of AB, the golden ratio is obtained in this comparison.

The golden ratio in comparison of shades is a very unique finding because it shows something of value in the layout of patterns in flowers. Examples of flowers that have this golden ratio besides wishbone flowers are Asian pigeonwings, *Dietes bicolor*, montbretia, and bilimbi.

Asian pigeonwings have a yellow pattern in the center of the flower and a small ribbon-like crown at the top. The results of the first measurement by comparing the total length (42.6 mm) with the length of the pattern plus the length of the ribbon (26.3 mm) get the ratio of 1.619. When the length of the pattern (26.3 mm) is compared to the length of the ribbon (16.2 mm), the golden ratio is 1.623. *Dietes bicolor* flower has 2 golden ratios related to the flower pattern. The first is ratio of the total length (64.3 mm) to the length of one crown to the pattern (39.7 mm), the obtained ratio is 1.619. The second is the ratio of the length to the center point (31.9 mm) with the length from the center point to the end of the pattern (19.7 mm) that resulted the same ratio of 1.619. Bilimbi is included in this category because the comparison found is similar to the flower in Figure 10, but this flower has a pink color near the pistil. The measurement result is 18.4 mm/11.4 mm and the resulted ratio is 1.614. Montbretia flowers have a spotted pattern that

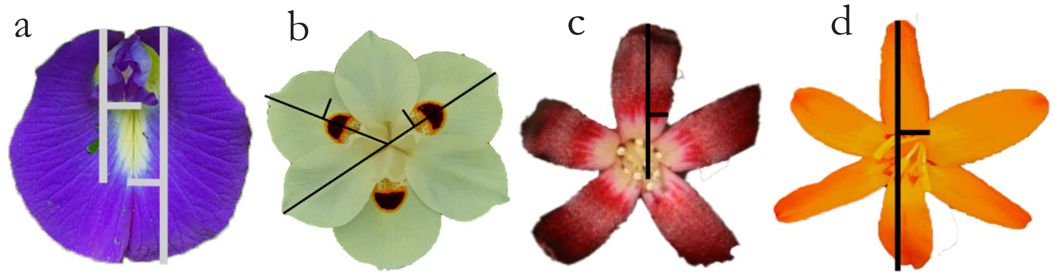

Figure 14. The golden ratio on the pattern of flowers. (a) Asian pigeonwings, (b) *Dietes bicolor*, (c) bilimbi, (d) montbretia

surrounds the flower pistil. The measurement result is 48.8 mm/30.2 mm and the golden ratio is 1.618.

The ratio of the height and width of the flower is the golden ratio that is obtained when the flower is viewed from the side. Some flowers that have this golden ratio are *Abutilon pictum*, Vegetable Hummingbird and *Houttuynia cordata*.

Abutilon pictum flower has a shape that resembles a lamp, the golden ratio obtained from the height and width ratio (54 mm/33.4 mm) produces a ratio of 1.617. The vegetable hummingbird flower with a size of 61.9 mm/38.3 mm has a ratio of 1.616. The Houttuynia cordata flower has a ratio of the width of one crown (19.2 mm) to the height of the pistil (11.9 mm) of 1.614.

Common jasmine, kopsia, and *Pavetta indica* flowers have a golden ratio in the ratio of the slanted side to the base. This comparison is similar to the comparison of long and short distances (see Figure 13), the difference between these two golden ratios is that the distance taken is the distance that produces a triangular shape.

Pavetta indica flower and common jasmine flower have a slanted side which is the value of the golden ratio, while in the kopsia flower, the perpendicular part is the value of the golden ratio. *Pavetta indica* flower has a slanted side length of 19.4 mm and a crown length of 12 mm, thus the raio is 1.617. Common jasmine has a size of 26.6 mm/16.5 mm thus the ratio is 1.615. The kopsia flower has a size of 28.4 mm/17.5 mm, and the ratio is 1.622. The result of the comparison of the slanted side and the base which resembles a triangle shape is in accordance with the statement of Livio (2002), that the golden ratio is found in an object and the shape of the triangle is an isosceles triangle and a gnomon triangle.

Circumference comparison is a finding that is not often found in other flowers. There are only 2 flowers with the golden ratio found on the circumference, namely lavender and Mysore trumpetvine flowers. These flowers do not have the golden ratio in area ratio, but the findings show that the circumference ratio is owned by these flowers.

Figure 15. The golden ratio between height and width. (a) *Abutilon pictum*, (b) Vegetable Hummingbird, (c) *Houttuynia cordata*

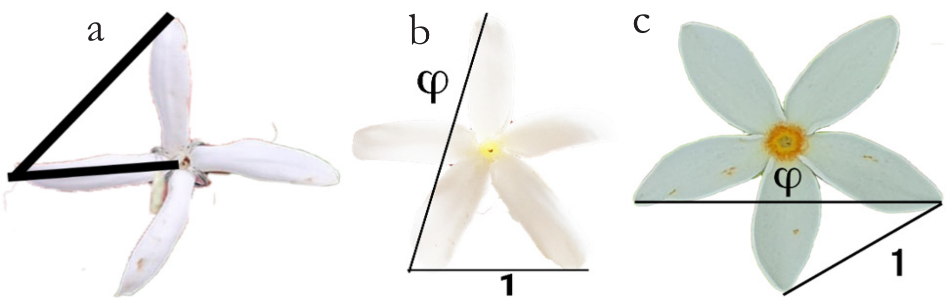

Figure 16. The golden ratio on slanted side and base. (a) *Pavetta indica*, (b) common jasmine, (c) kospia

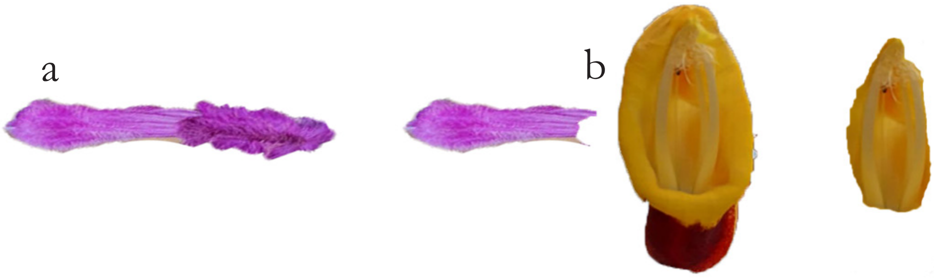

Figure 17. The golden ratio on the perimeter of the flower. (a) Lavender, (b) Mysore trumpetvine

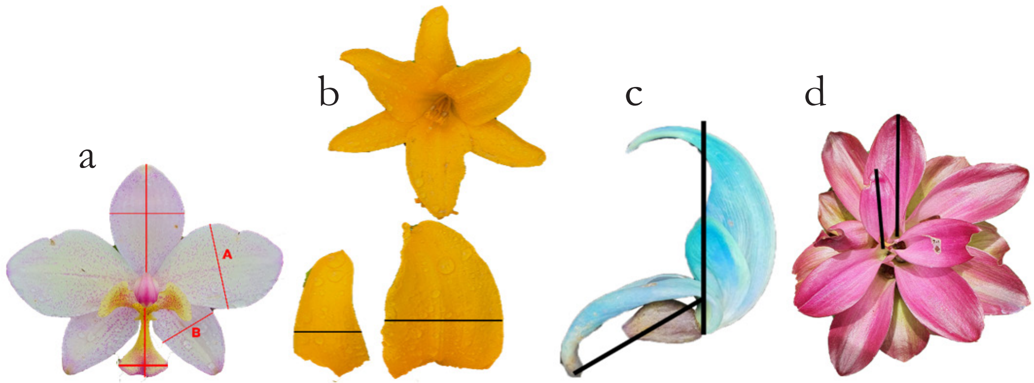

Figure 18. The golden ratio on the 2 different sizes of flower petals. (a) Philippine Ground Orchid, (b) yellow daylily, (c) jade vine, (d) turmeric

Lavender flowers have a ratio of the total circumference (61.212 mm) to the circumference of the lighter-colored parts (38.064 mm), thus the ratio is 1.608. Mysore trumpetvine flowers have a total circumference of 156.885 mm and a sac circumference of 97.283 mm, therefore have a ratio of 1.612.

Many flowers have petals that are the same size, but not all flowers have that morphology. The results of the golden ratio show that there is a size comparison between the 2 crowns. Examples in this comparison can be found in yellow daylily, Philippine ground orchid, jade vine, and turmeric (see Figure 18).

The Philippine ground orchids have a width ratio of larger crowns (A) and smaller crowns (B). This comparison is also found in the yellow daylily Flower, which is the width of the flower crown. The comparison of jade vine and turmeric flowers is found in the comparison of the length of 2 flower crowns.

B. Ecotourism Interpretation of the Golden Ratio in Flowers

Interpretation is an educational activity that aims to uncover meanings and relationships through the use of original objects with direct experience (Tilden, 2007). Interpretation activities can be carried out in ecotourism development, one of the subjects that can be applied is flowers. Interpretation can be successful if the program can give visitors something new to learn (Helianthi, 2022). This statement is a justification for Larsen's statement that interpretation is a guide, directing the audience from physical resources to the underlying meaning, from the tangible to the intangible, and from sight to insight (Larsen, 2011). By providing opportunities to connect with the meaning of resources, interpretations provoke public participation in resource management. Interpretation can help visitors to understand their relationship and their impact on the resource. The existence of interpretation is expected to help visitors to care.

Knowledge of the golden ratio in flowers can be the subject of an interpretation program because this discovery is something new and can be useful for visitors to understand the beauty of a flower. Visitors will get the meaning that a creation made by God is not done randomly. This is supported by Gardiner's statement that when looking at flowers that have a morphology based on the golden ratio, human consciousness will think that flowers are something beautiful (Gardiner, 2012). Based on the perspective of Muslims, the discovery of the golden ratio in flowers has been implicitly explained through the Holy Scriptures. Al-Quran in surah Al-Mulk (67) verse 3 and surah Al-Infitar (82) verse 7 which reads as follows.

Surah Al Mulk (67) verse 3

الَّذِيْ خَلَقَ سَبْعَ سَمٰوٰتٍ طِبَاقًاۗ مَا تَرٰى فِيْ خَلْقِ الرَّحْمٰنِ مِنْ تَفٰوُتٍۗ فَارْجِعِ الْبَصَرَۙ هَلْ تَرٰى مِنْ فُطُوْرٍ

3. "Who created the seven heavens in layers. You will not see anything unbalanced in the creation of a loving God. So, look once more, do you see anything that is flawed?"

Surah Al Infitar 82 verse 7

الَّذِيْ خَلَقَكَ فَسَوّٰىكَ فَعَدَلَكَۙ

7. "Who created you then perfected your events and made your (body structure) balanced"

It is explained in Tafsir Ibnu Katsir that Surah Al-Mulk verse 3 that all of God's creations are mutually compatible and balanced. In the next surah, it is explained that in fact humans were created in a balanced and very good form. The two verses of the holy Al-Quran show that there is nothing that is not balanced. The golden ratio is a comparison which, in addition to containing the value of beauty, has the meaning of balance to create something beautiful. The discovery of the golden ratio in flowers proves the truth of the holy verses of the Quran and the truth of the golden ratio theory. Surah Al Infitar 82 verse 7 has been researched that humans have a relationship with the golden ratio (Mardhiyati et al., 2018). The use of the holy verses of the Al-Quran to interpret the golden ratio can be a reference for interpreters in explaining the golden ratio to the audience so that they can better understand the importance of knowing the golden ratio in flowers.

The interpretation that can be outlined from the discovery of the golden ratio in flowers apart from a religious perspective can be seen in terms of the benefits of the plants studied. Based on literacy results, 65.4% of the flowers studied were flowers that had medicinal benefits, 20.7% had benefits for Indonesian culture and then they were only useful as ornamental plants. Yellow Allamanda flower, for example, is a medicinal plant that can prevent complications from malaria and swelling of the spleen (Munawaroh et al., 2017). Star of Bethlehem as eye drops to cure cataracts (Rahayu & Andini, 2019). Cambodian flowers have a close relationship with Balinese culture (Sujarwo & Lestari, 2018) as well as Jasmine and Ylang-ylang flowers which are widely used for ceremonies packaged in the form of 7 Kinds of Flowers (Ciptaningrum et al., 2022; Nurhadi et al., 2018). Knowledge of the benefits of flowers is something that is used as interesting material for tourists so that the ancient people might first see the beauty contained in flowers so that eventually they can find their benefits as medicinal plants and for the culture of the local community. Further, the measure of the golden ratio of a flower can also be used to determine the value of uniqueness in the One Score One Criteria Scoring System (Avenzora, 2008). The system shows that every single score given must be accompanied by the fulfillment of one discrete indicator requirement. The system shows that every single score given must be accompanied and fulfill the requirements of one discrete indicator, so the golden ratio can be used to assess the uniqueness of that system.

Based on all the previous explanations, the golden ratio of flowers is an interpretation of the value of beauty which has various benefits for living things, so that when it is focused on the ecotourism sector it is hoped that it will create a conservationist spirit for visitors. Starting with the understanding that something found in nature is the best form, followed by real benefits like ornamental plants, medicinal plants, and cultural values. Knowledge of the golden ratio of flowers for visitors is expected to improve their travel experience and foster a sense of care for flowers.

IV. CONCLUSION

The golden ratio of flowers is an example of an interesting finding to study that is useful for ecotourism interpretation that each flower species has certain parts that have aesthetic value, as shown by 12 types of golden ratio found in this study. These findings show that each flower has its own beauty value based on its shape. The shape of flowers can be assessed objectively by finding the golden ratio in flowers. It is hoped that these findings can foster the aesthetic spirit of visitors and a sense of care for flowers as objects that have beauty value. This material is very suitable to be used as part of an ecotourism interpretation because the aspect of aesthetics is one of the important aspects needed in implementing ecotourism in Indonesia.

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IDENTIFICATION OF LIGNOCELLULOSE-LIKE MATERIAL USING SPECTROSCOPY ANALYSIS

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IDENTIFICATION OF LIGNOCELLULOSE-LIKE MATERIAL USING SPECTROSCOPY ANALYSIS. Lignocellulose materials, such as bamboo, rattan, and wood, have been largely used for furniture and crafts. On the other hand, the utilization of lignocellulose-like materials, which have a similar texture and appearance to those from nature, has been increasing recently due to their superior durability. This research aimed to identify the lignocellulose-like material using spectroscopy analysis, such as Raman and Near Infrared (NIR), which is well-known as a non-destructive, quick, and accurate approach for material identification. We investigated four types of lignocellulose-like materials that were provided by Dewan Serat Indonesia (The Indonesian Fiber Council) from an industry that produces them. The NIR analysis was performed at wavenumbers 10,000-4,000 cm^{-1}. The natural lignocellulose (bamboo and wood) and the polymers (polyethylene and polypropylene) were used as standards. Raman analysis was further employed to identify the composition of selected lignocellulose-like materials by comparing their spectra with the library software. The results showed that the original NIR spectra of lignocellulose-like and those natural materials were different, indicating that the NIR analysis can differentiate those materials. The NIR spectra of lignocellulose-like materials were similar to those of polyethylene spectra. Those lignocellulose-like were also identified as polyethylene due to the similarity of the Raman spectra and their library spectra.

Keywords: Near Infrared spectroscopy, Raman spectroscopy, lignocellulose, lignocellulose-like materials, polyethylene

IDENTIFIKASI BAHAN SERUPA LIGNOSELULOSA MENGGUNAKAN ANALISIS SPEKTROSKOPI. Material lignoselulosa seperti bambu, rotan, dan kayu telah banyak digunakan untuk mebel dan kerajinan. Disisi lain, pemanfaatan material tiruan, dimana bahan tersebut mempunyai kesamaan tekstur dan penampilannya dengan lignoselulosa dari alam semakin meningkat. Hal ini juga didorong oleh sifat keawetannya yang sangat tinggi sehingga menjadi salah satu bahan pengganti yang potensial. Tujuan dari penelitian ini adalah untuk mengidentifikasi material tiruan lignoselulosa dengan analisa spektroskopi Near Infrared dan Raman, dimana kedua alat ini mempunyai keunggulan karena cepat, tidak merusak, dan memiliki keakuratan tinggi untuk melakukan identifikasi. Penelitian ini menggunakan empat jenis material tiruan lignoselusa yang diperoleh dari Dewan Serat Indonesia. Bahan ini merupakan salah satu produk yang dihasilkan oleh Perusahaan luar negeri. Analisa Near Infrared dilakukan dengan perekaman spektra pada nomor gelombang 10.000-4.000 cm^{-1}. Sebagai pembanding, digunakan material lignoselulosa alami dan juga polimer seperti bambu, kayu, poli etilen, dan poli propilen. Sedangkan analisa dengan Raman dilakukan dengan membandingkan spektra Raman dari material tersebut dengan spektra yang ada pada software Raman spektroskopi. Hasil penelitian menunjukkan bahwa spektra original Near Infrared dari bahan tersebut sangat berbeda dengan bahan lignoselulosa alami, yang mengindikasikan bahwa analisa tersebut dapat digunakan untuk membedakan bahan lignoselulosa alami dan tiruan. Selain itu, spektra

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Near Infrared dari bahan tiruan mempunyai kemiripan dengan polimer poli etilen. Hal ini juga dikuatkan dengan hasil dari analisa Raman, dimana spektranya sama dengan spektra poli etilen pada data base software Raman.

Kata kunci: Near Infrared, Raman spektroskopi, . lignoselulosa, lignoselulosa tiruan, poli etilen

I. INTRODUCTION

Indonesia is well known for its mega biodiversity in its natural resources, including natural fibers or lignocellulosic materials, such as wood, bamboo, and rattan. For instance, almost 11.5% of all bamboo species in the world are grown in Indonesia, which consists of 161 species from 12 families (Widjaja et al., 2014). In addition, Indonesia has 4,000 wood species, and hundreds of those species have been traded with high commercial values (Damayanti et al., 2019). The abundance of natural resources plays an important role in helping developing countries maximize the potential utilization of those resources for their economic growth. Furthermore, natural resources are known as bio-renewable and eco-friendly materials (Karimah et al., 2021), thus their utilization can reduce the risk of environmental issues.

Lignocellulose materials have a wide range of applications, including structural uses in housing and building materials, furniture, and crafts. Moreover, the utilization of bamboo and wood as raw materials for crafts has been increasing and becoming one of the fastest-growing micro, small, and medium enterprises of the creative economic sector in Indonesia, which contributes to 60% of Gross Domestic Products (GDP) (Christine, Dachyar, & Nurcahyo, 2019; Herliana, Crestofel Lantu, Rosmiati, Chaerudin, & Lawiyah, 2022). As an organic material, lignocellulose has issues related to its durability, stability, and performance against weather and organisms (Himmi et al., 2017; Ismayati et al., 2011). On the other hand, the development of lignocellulose-like materials is also rising, which have similar texture, surface, and appearance to natural lignocellulose. One of the producers of lignocellulose-like materials claimed that their products are very resistant and durable against weather, moisture, mold, and termites, thus indicating the product is superior to the natural one. However, the increasing awareness of people toward their environment has led to the utilization of natural resources as the main raw materials for replacing hazardous and synthetic materials (Karimah et al., 2021). Thus, material identification to differentiate natural and lignocellulose-like materials is needed.

Direct investigation of the sample is usually destructive and requires a large sample, labor intensives, and time-consuming. Therefore, rapid analysis, non-destructive, and accurate method is urgently required to identify the natural and lignocellulose-like materials. Spectroscopy analysis using Near Infrared (NIR) and Raman spectroscopy might be able to meet all those requirements (Ayanleye & Avramidis, 2021; Deneva et al., 2020).

NIR is a region of the electromagnetic spectrum at the wave number 12,820-4,000 cm^{-1} (wavelength 780-2,500 nm) (Schwanninger, Rodrigues, & Fackler, 2011). The combination of chemometrics analysis and NIR spectroscopy is very useful as qualitative and quantitative methods (Tsuchikawa & Kobori, 2015). As a qualitative analysis, the principle of using NIR is comparing spectra of unknown and known materials (Wang, Xiang, Tang, Chen, & Xu, 2022), which could be used to identify some wood species (Adi et al., 2020; Hwang, Horikawa, Lee, & Sugiyama, 2016). The NIR range is suitable for measuring organic materials containing high moisture due to the smaller molar absorptivity compared to the infrared (IR) range (Tsuchikawa & Kobori, 2015). In addition, NIR spectroscopy is less strong than IR spectroscopy, which enables the thick polymer samples to be analyzed without suffering from the light. By using NIR spectroscopy, the absorption is very weak, making it possible to measure the NIR transmittance or reflectance without any pretreatment (Shinzawa et al., 2021). Moreover, analyzing the sort of plastic could be processed by NIR with high speed measurements, radiation penetration depth, and signal-to-noise ratio (Xia, Huang, Li, Xiong, & Min, 2021). On the other hand, Raman spectroscopy is popular as a non-destructive test for woody materials (Yamauchi, Iijima, & Doi, 2005). Raman spectroscopy is useful for detecting the vibrations of symmetrical structures and is very sensitive to polarizability (Gierlinger, 2018). In addition, it has important information regarding the structural and chemical composition (Amjad, Ullah, Khan, Bilal, & Khan, 2018). Raman spectroscopy is not only used to identify organic materials, but it is also used to identify polymers (Kida, Sasaki, Hiejima, Maeda, & Nitta, 2020; Zhou, Liu, Hao, & Liu, 2021). Therefore, this study was conducted to identify natural and lignocellulose-like materials by comparing their NIR and Raman spectra.

II. MATERIAL AND METHOD

A. Materials

This study investigated four types of lignocellulose-like materials, which have similar appearance and texture to wood and bamboo. These materials were obtained from Dewan Serat Indonesia (The Indonesian Fiber Council) in the form of raw materials in the square form, not as finished products (Figure 1. A-D). The samples were produced by a foreign company that it seems made from some plastic polymers. Several types of wood and bamboo species were selected at random and subsequently analyzed as the standard for natural lignocellulose. Eight commercial wood species from Indonesia were used for comparison, namely: Balau, heavy Red Meranti, White Meranti (obtained from commercial market around Bogor-Indonesia); Old Teak, Platinum Teak, Jati Plus (fast-growing Teak) (obtained from the National Research and Innovation Agency of Indonesia-BRIN); *Shorea bracteolata*, and *Shorea parvifolia* (obtained from *Xylarium Bogoriense*). Furthermore, four bamboo species from the bamboo collection field at the BRIN in Cibinong, such as *Dendrocalamus asper*, *Bambusa vulgaris*, *Giganthocloa atter*, and *Bambusa maculata* Widjaja, were also investigated. In addition, low-density polyethylene (PE) and polypropylene (PP) were also analyzed as standards for plastics.

B. Near Infrared and Raman Spectroscopy Methods

The samples were analyzed directly in the NIR machine (Frontier, PerkinElmer, Massachusetts, USA) to get the spectra at wavenumber 10,000-4,000 cm^{-1}, with 32 scans and a resolution of 16 cm^{-1}. The NIR spectra were set to provide a graph with absorbance and wavenumber. The determination of

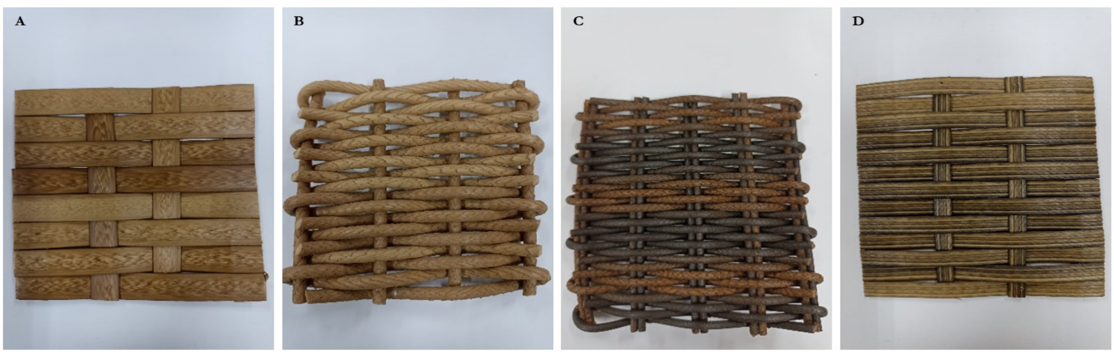

Figure 1. The samples of lignocellulose-like materials: A&D the shape is rectangular with different colours; B&C the shape is rounded with different colours

natural and lignocellulose-like materials was carried out by comparing the original spectra of those materials and the spectra of PE and PP. However, additional classification procedures would be applied if the original spectra exhibited comparable shapes in both natural and lignocellulose-like materials. Raman Spectroscopy analysis (LabRam HR Evolution Confocal Raman Microscope, Horiba France SAS, Longjumeau, France) was conducted at the Integrated Laboratory of Bioproducts (iLab)-BRIN, with the laser 532 nm and grating 600. The other parameters on the Raman analysis were ND filter 50%, objective 100x visible, acquisition time 12 seconds, and accumulation 10. Then, an integrated identifier software in Raman software was used to identify the composition of all samples by comparing their spectra to the database (Bio-Rad Laboratories).

III. RESULT AND DISCUSSION

A. Near Infrared Spectroscopy

A graphical representation of the NIR original spectra of natural lignocellulose samples of 8 wood species (A) and 4 bamboo species (B) is visualized in Figure 2. The graphs indicate that there were identical shapes and bands for all-natural lignocellulose. The discrepancies of the original spectra are only for the absorbance value, where the wood species has a big variation compared to those bamboo species. Adi et al. (2020) revealed the relationship between density and their NIR absorbance values shows that the high density tends to have a positive correlation with absorbance, for instance, Balau (0.76 g/cm^3) has a higher absorbance value than red Meranti (0.64g/cm^3). This result is also similar to that of Belangke bamboo, in which the upper

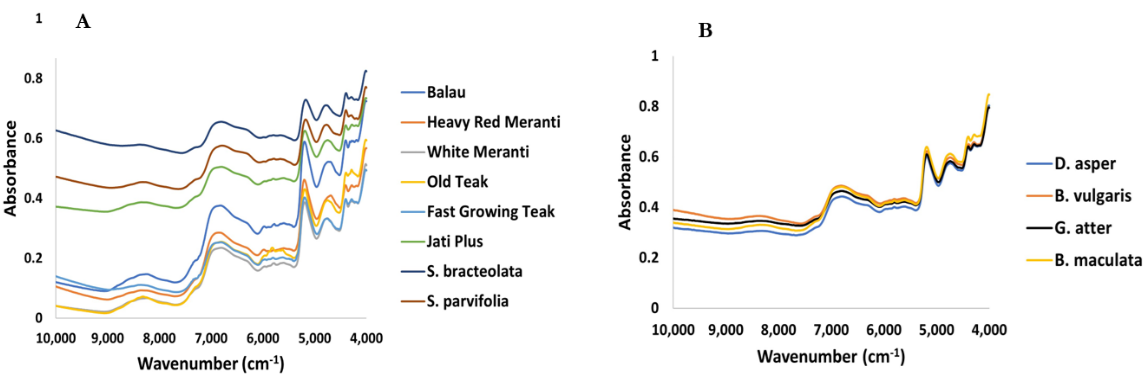

Figure 2. The NIR original spectra at wavenumber 10,000-4,000 cm^{-1} of wood species (A) and bamboo species (B)

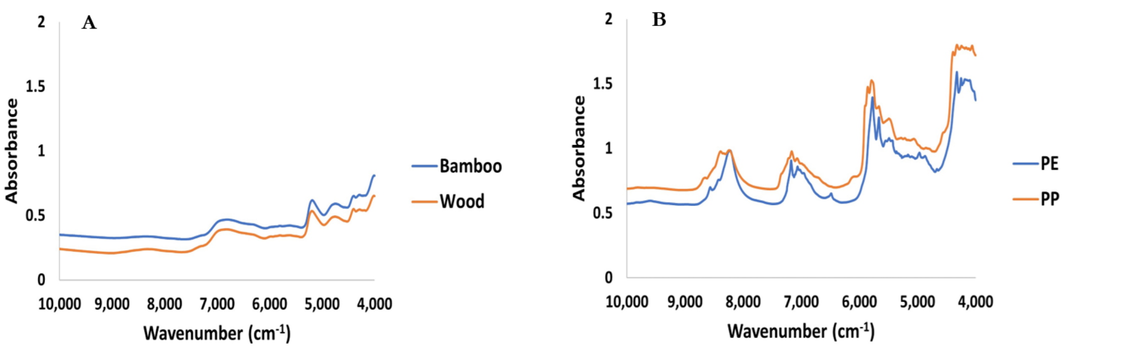

Figure 3 The average of NIR original spectra at wavenumber 10,000-4,000 cm^{-1} of wood and bamboo species (A); polymer standard for PP and PE (B)

part has higher absorbance than the other part since the top part has the highest density value (Iswanto et al., 2022). However, this study used several wood and bamboo species as a standard only.

The mean spectra for wood and bamboo species revealed that their typical spectra were in a similar shape (Figure 3A), although there were different values of absorbance, baseline shift, and some flat curves. This phenomenon usually occurs in the original spectra, which makes the interpretation of the bands very difficult. The chemical and structural characteristics of the cell walls have an impact on NIR spectroscopy because it is sensitive to functional groups (Horikawa, Mizuno-Tazuru, & Sugiyama, 2015). The spectra of plastic materials, such as PE and PP, are completely different from those of organic materials (Figure 3B). The basic concept of NIRS qualitative analysis is comparing the spectra of unidentified materials with those of known samples spectra (Wang et al., 2022). Consequently, it had been acceptable to easily distinguish between lignocellulose and plastic materials by just comparing the original spectra directly. The spectra of polymers contain broad overtones of stretching and bending vibrational bands due to the light reflectance of the polymers and the NIR light source (Michel et al., 2020). PE and PP have different bands in the region of 6,500 cm^{-1} and 5,500-5,000 cm^{-1}, which might be useful information for differentiating both materials. Some treatments, like the first derivative and

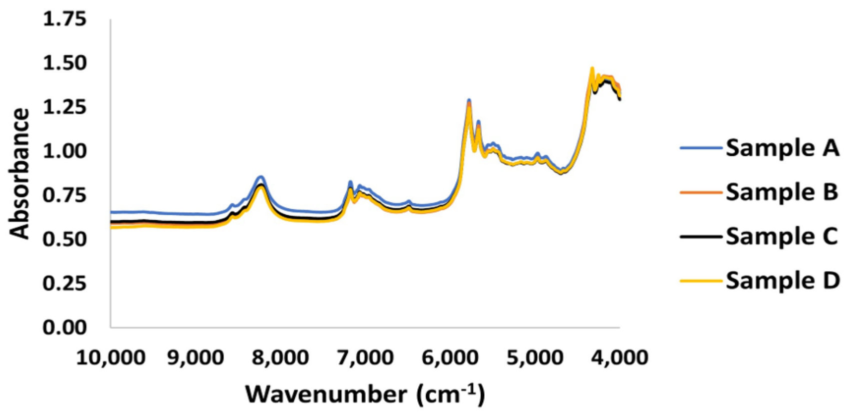

Figure 4. The average of NIR original spectra at wavenumber 10,000-4,000 cm^{-1} of 4 types of lignocellulose-like materials

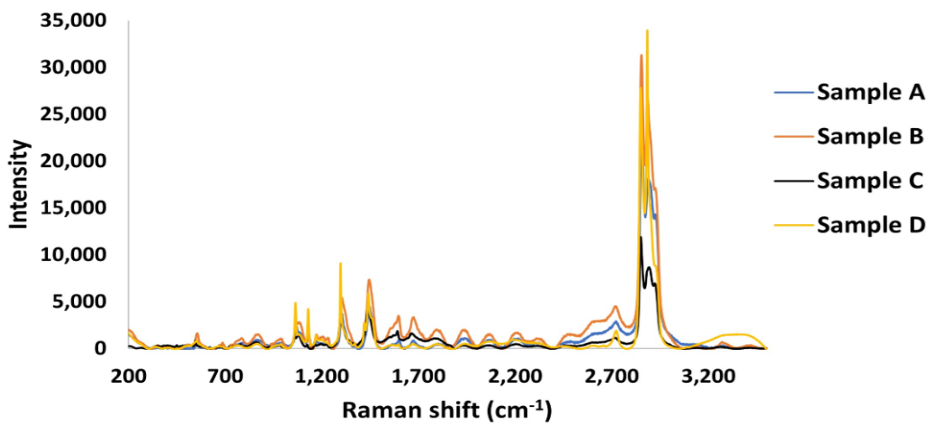

Figure 5. The Raman spectra of 4 types of lignocellulose-like materials

Savitzky-Golay filter, could make the bands more clearly visible (Duan & Li, 2021).

Figure 4 shows the mean of original NIR spectra of 4 types of lignocellulose-like material at 10,000-4,000 cm^{-1}. At first glance, the absorbance values of all samples were identical, and it seems the graphs overlap. It was presumed that the raw materials used in all samples were comparable. The classification of unknown materials in optical spectroscopy usually uses visual inspection of the spectrum (Tuncer, Dogu, & Akdeniz, 2021). By comparing the spectra of lignocellulose-like material to the standard in Figure 3A, it was clearly seen that the raw material of lignocellulose-like was not made from the natural material. According to Figure 3B, the spectra of the 4 samples were compared to the PE spectra due to the appearance of some bands in wavenumber 6,490 cm^{-1} and the region around 5,500-5,000 cm^{-1}; thus, it was supposed that all the samples were made of PE plastic.

B. Raman Spectroscopy

Raman spectra of all lignocellulose samples are presented in Figure 5. In general, the spectra showed similar shapes, although there were some noise peaks on specific Raman shifts. Getting smooth spectra in Raman spectroscopy is challenging. The fluorescence interference has influenced the variation of baseline modeling; thus, choosing the appropriate window for polynomial fitting was required to minimize the noise (Amigo, Babamoradi, & Elcoroaristizabal, 2015). Furthermore, setting the proper accumulation and acquisition time is also needed in the analysis of Raman spectroscopy. This study found that there were at least 5 peaks in the Raman spectra, with different settings of acquisition times and accumulation. These peaks were at Raman shift 1,100 cm^{-1}, 1,250 cm^{-1}, 1,450 cm^{-1}, 2,700 cm^{-1}, and 2,850 cm^{-1}.

Micro Confocal Hyperspectral 3D Raman Spectroscopy in this study was completed with software to determine the spectra based on comparison with the spectra database from Bio-Rad Laboratories. The results revealed that 4 types of synthetic lignocellulose materials had different compositions. The sample 1 was identified as High-Density Polyethylene (HDPE), while sample 2, sample 3, and sample 4 were Low-Density Polyethylene (LDPE), LDPE + acrylic acid, and LDPE, respectively. PE was a base structure for that synthetic lignocellulose, even though 2 samples have different PE compositions. These findings were in accordance with those from the NIR spectra. Kniggendorf, Wetzel, & Roth (2019) reported that PE has Raman bands at 2,850 cm^{-1} and 2,884 cm^{-1}. All samples in this study also had bands at 2,850 cm^{-1}, which was the highest peak and contained -CH2 and -CH3 stretching vibrations (Gopanna, Mandapati, Thomas, Rajan, & Chavali, 2019).

Several factors might have contributed to the variances in PE structure in these samples, such as treatment processes to the Raman spectra, the surface of the sample, and some additives or colors to the samples. Selecting the proper window for polynomial fitting plays a crucial role. For instance, using a small window has the effect of generating noise, which means new bands appear in the spectrum. In contrast, choosing a wide window could eliminate some bands (Amigo et al., 2015). The surface characteristics have an effect on adding noise to the signal (Duan & Li, 2021). Adding some color and additives could change the spectrum (Michel et al., 2020). LDPE and HDPE have similar molecular structures (Duan & Li, 2021), so differentiating those materials by molecular vibrations is challenging.

IV. CONCLUSION

Determination between natural and lignocellulose-like materials was successfully introduced by using NIR and Raman spectroscopy. These techniques were non-destructive, fast, reliable, and traceable. The original spectra of natural and lignocellulose-like were very different, which indicated that the lignocellulose-like was made from synthetic material. By comparing the standard spectra of plastics, the composition of these materials was identified as LDPE. The Raman spectra corresponded to the NIR analysis since the spectra were similar to the LDPE spectra reference, even though Sample 1 was identical with HDPE and Sample 3 consisted of LDPE and acrylic acid.

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GUIDELINE FOR AUTHORS

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In Text Citation :

Water is a necessary part of every reasons's diet and of all the nutrient a body needs to function, it requires more water each daya than any other nutrients a body needs to function, it requires more water each day than any other nutrient (Whitney & Rolfes, 2011)

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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JUDUL HARUS RINGKAS, INFORMATIF DAN SECARA JELAS MEREFLEKSIKAN ISI MANUSKRIP. Tuliskan terjemahan abstrak dalam bahasa Indonesia. Abstrak tidak lebih dari 250 kata. Abstrak menjelaskan keseluruhan isi artikel. Abstrak meliputi maksud, tujuan penelitian, metodologi yang digunakan, hasil dan kesimpulan. Maksud penelitian harus menjelaskan secara ringkas permasalahan yang diteliti menggunakan bahasa ilmiah umum yang mudah dimengerti oleh pembaca. Teknologi atau metodologi yang digunakan untuk pemecahan permasalahan penelitian harus dicantumkan secara lengkap dan ringkas dalam abstrak. Ringkasan hasil penelitian dan temuannya ditampilkan dalam ringkasan singkat. Kesimpulan harus menyatakan outcome yang dicapai dalam kegiatan penelitian.

Kata kunci: Empat sampai enam kata kunci untuk keperluan indeksasi dan abstraksi. Setiap kata mencakup isu yang dibahas dan diurutkan secara alphabet dipisahkan oleh tanda koma

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Note:
- There should no nonstandard abbreviations, acknowledgements of support, references or footnotes in the abstract.
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I. INTRODUCTION

State the objectives of the work and provide an adequate background of the research objectives, avoiding a detailed literature survey or summary of the results. To prepare your manuscript, a template can be downloaded from: http://ejournal.forda-mof.org/ejournal-litbang/files/IJFR_Template.docx

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This chapter of theory/calculation is noncompulsory or optional. A theory or detailed calculation should be extended, not repeated, in the introduction. The theory of calculation (if any) mentioned should lay the foundation of the work.

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Write the process of inspecting, cleaning, transforming and modeling data with the goal of discovering useful information, suggesting conclusions and supporting decision-making.

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A brief summary of the possible clinical implications of your work is required in the conclusion section. Conclusion contains the main points of the article. It should not replicate the abstract, but might elaborate the significant results, possible applications and extensions of the work.

ACKNOWLEDGEMENT

Acknowledgement is a must for persons or organizations who that have already helped the authors in many ways. Sponsor and financial support acknowledgements may also be placed in this section. Use the singular heading even if you have many acknowledgements.

REFERENCES

At least 10 references are listed according to American Psycological Association (APA) referencing style, 6th edition. References must be listed in alphabetical order by another name. Eighty percent of references should be cited from primary sources and published in the last five years. To properly credit the information sources, please use citation tools such as Mendeley or EndNote to create a bibliography, references and in-text citations. Mendeley is a free reference manager that can be downloaded at https://www.mendeley.com/download-mendeley-desktop/.

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