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Intensification of Silviculture Techniques in Community Forest Management to Realize the Acceleration of SDG's Point 13: Handling Climate Change

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ABSTRACT
Global climate change has become an urgent issue affecting land quality, especially forest areas. Forests are important in mitigating climate change by absorbing carbon and storing greenhouse gases. Community forests, which are managed by communities on private land, have great potential to reduce carbon emissions. However, community forest management is still suboptimal due to limited knowledge of the application of effective silvicultural techniques. This study aims to provide recommendations for community forest management by intensifying silvicultural techniques, such as plant spacing and plant species selection, to reduce fire risk and support climate change mitigation. The method used was a systematic review of 30 relevant scientific articles. The literature used came from books and national and international journal articles accessed through Google Scholar, Springer and ScienceDirect databases. Articles were selected through a selection process based on the relevance of the title, abstract, and overall content. The results showed that a planting distance of 4×4 meters or 4×3 meters is the most optimal for tree growth and allows the implementation of an agroforestry system. In addition, plant species such as *Swietenia macrophylla* and *Gliricidia sepium* proved effective as fire barriers due to their evergreen characteristics that can reduce the amount of litter as fire fuel. In conclusion, intensive silvicultural techniques can increase the effectiveness of community forest management in sequestering carbon, reducing the risk of forest fires, and supporting climate change mitigation efforts. This research provides recommendations that community forest managers can apply to improve environmental sustainability.

Introduction

The world's climate has changed significantly in the last 65 years with further shifts expected to occur in the 21st century. These changes have real implications in the form of global warming and are a crucial issue because they have influence in various sectors. Global warming is one of the phenomena of climate change caused by an increase in greenhouse gases (GHGs) in the atmosphere. Factors that cause climate change include volcanic eruptions, variations in sunlight, and anthropogenic activities such as land use change and fossil fuel use that have a real impact (Venäläinen et al., 2020).

The correlation between the impacts of climate change on various sectors around the world is complex. The ecological, environmental, socio-political, and socio-economic domains are sectors that are heavily affected by climate change. One of the implications of climate change on a global scale on the ecological and environmental sectors is the increase in extreme weather which is characterized by an increase in the average temperature of the earth's surface. Increased extreme weather can decrease the growth and development rate of forests, cause fluctuations in seasonal patterns that can affect animal migration patterns, and increase the population of plant-destroying organisms (Anderegg et al., 2020; Aprianto et al., 2024; Pinontoan et al., 2022; Ruiu, 2023).

When viewed from a wider spectrum, climate change can disrupt the balance of forest ecosystems that have an important role in stabilizing global temperatures, controlling the carbon cycle, and nitrogen cycle. This needs to be a major concern considering the importance of balancing forest ecosystems in ensuring sustainability in the world. The forest and other land use (FOLU) sector is strategically positioned to ensure the achievement of the Paris Agreement's goal of limiting global temperature rise. Through the vision in the Long Term Strategy on Low Carbon and Climate Resilience (LTS-LCCR). Indonesia will increase the reduction of GHG emissions with a peak net emission in all sectors by 2030 of 1,244 million tons of CO2e or the equivalent of 4.23 tons of CO2e per capita (MENLHK, 2022). One of the actualizations of achieving these goals is through the use and utilization of forest areas. This is also in line with the Sustainable Development Goals (SDG's) in ensuring climate resilience.

Addressing climate change is the 13th goal of the SDGs which consists of 5 targets through 8 indicators. These targets are increasing climate change resilience and adaptation, integrating climate change anticipation, increasing human resources, implementing international treaty commitments, and improving climate change management. A quick response is needed as a mitigation step and appropriate actions as an adaptation step at the site level that can increase the chance of avoiding further permanent damage (Umar, 2021). The use and management of community forests can be one of the steps to achieve the target of sustainable development goals.

People's forests are forests that are located on land that is encumbered with property rights so that all resources are fully owned by the people. The development of community forests has been proven to support the economy in rural areas and solutions to environmental problems (Joa & Schraml, 2020). Vegetation communities in community forests can reduce carbon emissions and produce oxygen through photosynthesis mechanisms. If the optimization of community forests goes well, then handling climate change at the site level will also support the success of reducing carbon emissions. Therefore, it is necessary to manage community forests through intensive strategies and methods to support the acceleration of SDG's point 13: Climate Change Management.

This paper aims to determine the ability of community forests to absorb carbon emissions, understand the mechanism of intensification of silviculture techniques in community forest management, and evaluate the application of silviculture techniques in dealing with climate change and other benefits. This research is expected to provide recommendations for effective community forest management through silviculture techniques, in order to reduce the risk of forest fires and support climate change management.

Materials and Methods

The method used in this paper is Systematic Review which is obtained from 30 scientific articles. Literature searches come from reputable national and international books, journal articles obtained from GoogleSchoolar, Springer, and ScienceDirect databases. In addition, laws, ministerial regulations, and ministerial decrees are also used that are relevant to the title of the paper. The sources obtained are selected with the latest 5 years, namely from 2019-2024. The search for literature sources used the keywords "people's forests", "silviculture", "climate change", and "forest fires". After obtaining a source of literature, the next stage is to select an article by assessing the relevance of the title, selecting abstracts, and then reviewing the whole. Followed by descriptive interpretation and analysis.

Results and Discussions

Greenhouse Gas Emissions

Greenhouse Gases (GHGs) play an important role in global climate change. Several sectors that produce GHG emissions according to BPS data (2020) include the energy, FOLU, agriculture, IPPU, waste, and forest fire sectors (Figure 1).

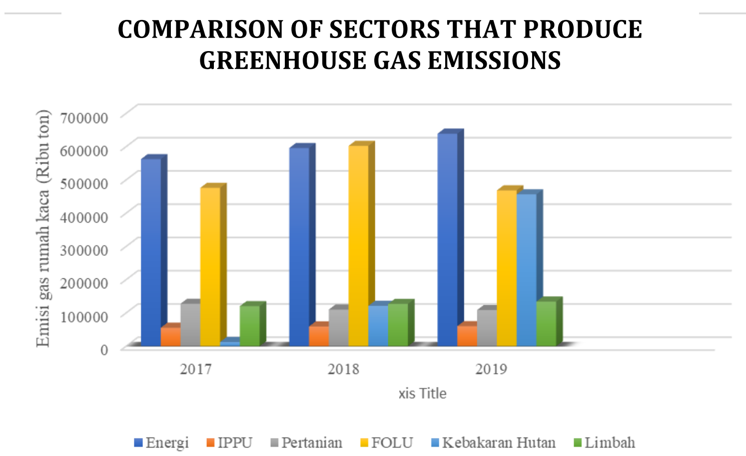


Figure 1. Comparison Graph of sectors that produce GHG emissions

Source: BPS, 2020

1) Energy Sector

Based on data from BPS (2020) related to various sectors that produce greenhouse gas emissions from 2017 to 2019, the energy sector is one of the largest contributors to emissions compared to other sectors and continues to increase from year to year followed by FOLU, forest fires, waste, agriculture, and IPPU. The energy sector produced carbon emissions of 562 million tons in 2017, 595 million tons in 2018, and 638 million tons in 2019 (Figure 1). Pratiwi (2021) stated that the energy sector plays an important role in carrying out economic activities both for consumption needs and production activities so that the emissions produced by the energy sector are the highest. Carbon dioxide produced from energy use dominates around 99% of greenhouse gas emissions that can trigger global warming (Budiwan, 2020) so that even though energy use supports economic growth, it still has a negative impact on environmental quality and increases the intensity of greenhouse gas emissions.

2) FOLU sector

The forestry sector is one of the largest contributors to carbon emissions through land degradation and deforestation that continues to occur. Wahyuni and Suranto (2021) stated that deforestation is a condition for the decline of forest areas due to land conventions for settlements, agriculture, mining, and infrastructure needs. High deforestation rates cause massive loss of forest areas and have a negative impact on environmental sustainability, one of which is triggering climate change. In 2017, FOLU produced 467 million tons of carbon and increased to 602 million tons in 2018 (Figure 1). Deforestation has a major impact on climate change due to the inability of areas to absorb carbon dioxide in the air due to the loss of vegetation on site.

In 2019, there was a decrease in emissions to 468 million tons (Figure 1). This decline is due to forest and land rehabilitation efforts to reduce the rate of damage from the forestry sector. The central government provides funding for Low Carbon Development (PRK) in development activities that have a direct impact on reducing emissions. This is supported by Risandi and Sirait (2021) who stated that in 2019 there was a significant increase in the budget for land rehabilitation activities so as to allow for the optimization of forest land improvement.

3) Forest Fires

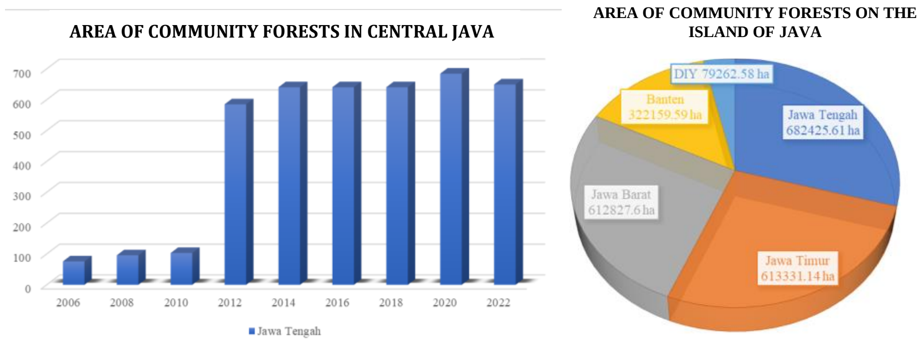
Forest fires are also a major contributor to greenhouse gas emissions. In 2017, the number of emissions resulting from forest fires was quite small, amounting to 12.51 million tons per year, then increased to 121 million tons in 2018 and continued to increase significantly to 456 million tons in 2019 (Figure 1). This increase occurred drastically due to forest and land fires in 6 provinces in Indonesia, especially Central Kalimantan (BNPB, 2019). This fire reached 857,756 hectares which occurred on 630,451 ha of mineral land and 227,304 ha of peatland (PPID-KLHK, 2019). This makes Indonesia the third contributor to carbon gas emissions after the United States and China by 80% caused by forest fires (Han *et al*., 2019).

Carbon dioxide is a gas that is released in large quantities from forest fires that can increase the accumulation of greenhouse gases in the atmosphere and result in an increase in temperature (Dini et al., 2022). Therefore, the government has sought various ways to minimize the occurrence of forest fires, including through policy making, *monitoring* fire points in forest areas, rewetting peatlands, and involving various parties to support various strategies that have been launched by the government.

Several other sectors also contribute to emissions that continue to cause an increase in the number of greenhouse gas emissions and have an impact on climate change. The government continues to make efforts and strategies to reduce the amount of emissions emitted from various sectors. In this case, cooperation and assistance from various parties are needed so that the goals can be achieved and various problems that cause climate change can be minimized, one of which is through the utilization of community forest areas to remain productive.

Potential Area of Community Forest

People's forests are closely related to the lives of Indonesia people and hold great potential. The existence of community forests is one of the sources of providing for community needs, especially timber. This shows that community forests have a significant impact on people's economic income.



a b

Figure 2. (a) Bar diagram of the comparison of the area of people's forests in Central Java per year (b) Circle diagram of the difference in the area of people's forests between provinces on the island of Java

Source: (BPS, 2020, 2024)

The area of community forests in Central Java continues to grow from year to year (Figure 2). According to data from BPS Central Java (2024), the area of community forests in Central Java is 649,348 ha. Figure 2 (a) presents a diagram in the form of an increase in the number of community forest areas in the Central Java region from 2006 to 2022. The total area of community forests before 2010 did not reach 100,000 ha and experienced a drastic increase to 500,000 hectares in 2012. This is because the increasing development of community forests results from forest and land rehabilitation programs implemented by the government and is supported by the high demand for timber commodities by the community. In addition, the existence of agricultural and plantation areas during the harvest period will be classified as community forests (Fariz et al., 2021). Figure 2 (b) shows a comparison of the percentage of community forest area between provinces on the island of Java. The largest area of community forests is in Central Java Province with an area of 682,425.61 ha, East Java with an area of 613,331.14 ha, West Java with an area of 612,827.6 ha, Banten with an area of 322,159.59, and Yogyakarta with an area of 79,262.58 ha.

The potential area of community forests in each province has a positive correlation with the environment. Vegetation in community forests can absorb carbon through the process of photosynthesis and some of it is stored in the form of biomass and produces O2. Rosianty et al. (2020) stated that half of the biomass contained in the biomass is carbon with a percentage of 50% so that if the total volume of the stand (biomass) in the community forest land is 100 tons/ha/year, the carbon absorption in the land is 50 tons/ha/year. This is in line with Irundu's (2023) research which analyzed a total of 90.62 tons of biomass per ha on people's land capable of absorbing carbon of 42.59 tons per ha. The existence of community forests in each area has its own characteristics according to its designation. The variety of plant types in community forests is closely related to the variety of diverse needs. The use of community forest land through agroforestry can be one of the management approaches. Agroforestry-based community forest management contributes 55.8% to 75% of total household income (Aprilliyanto et al., 2020; Larasati et al., 2020).

Analysis of Community Forest Management

Community forest management has formed a variety of structured and cultural activities. These structured activities have a comprehensive management pattern and institutional system with commercial, subsystem, and environmental objectives that will be an important instrument in sustainable life. In order to support climate change mitigation efforts, the government encourages the development of community forests to make a real contribution to the absorption of carbon emissions and prevent deforestation and forest degradation. In this case, the owner of community forest land has a big role in direct management. The government is developing the community forest business by establishing the Public Service Agency of the Forest Development Financing Center (BLU Pusat P2H) which is a work unit of the Ministry of Environment and Forestry by implementing forest development financing to delay tree cutting (PPID-KLHK, 2019). BLU Central P2H provides a Revolving Fund Facility (FDB) to increase people's economic empowerment, increase forest productivity, and improve environmental quality.

Community forest management carried out by the community has a different system and method in each region. Differences in community forest management are triggered by the characteristics of the area, stands, and other constituent components. On the characteristics of sloping land, the agroforestry method can be carried out with a pattern of guludan and rorak terraces to facilitate water infiltration into the soil. In addition, community forest farmers also manage land by adjusting the spacing of tree plantings so that they can produce wood sustainably and sustainably to meet market demand.

The limited knowledge of the community about community forest management is the main problem. There are people who let their land and plant trees with irregular patterns. The existence of litter and improper selection of plant types for forest fire prevention can reduce the productivity of community forests. Therefore, community independence is needed in designing an effective and efficient community forest management strategy. Smallholder forest farmers can increase their knowledge in community forest management through collaboration with *stakeholders*, such as local governments, academics, and NGOs. An example of cooperation that has been carried out is the partnership HR policy which aims to improve the welfare of the community, improve the quality and quantity of stands, a guaranteed market, and increase the capacity of farmers. Community forest management will be more optimal if the improvement is carried out by applying silviculture techniques through the selection of more effective planting distances for tree growth and the selection of plant types.

Silviculture Engineering Intensification Design

1) Selection of Planting Distance

Planting distance affects the growth of the stand. The planting distances that are commonly applied for forestry stands are 3×3 m, 4×4 m or 3×4 m (Arum, 2022; Toaha & Beddu, 2024). The results of Larasati's (2019) research show that at a planting distance of 4×4 m it can produce high growth, optimal diameter, and the best productivity. Nath *et al.* (2020) revealed another result, namely that a planting distance of 4×3 m will produce trees that have a survival percentage of up to 97%, have a maximum tree height, and a large diameter. The selection of planting distances of 4×4 m and 4×3 m will have a scope of space availability that is used for intercropping systems or agroforestry. Optimizing the land between the main crops will also prevent the emergence of weeds that will increase nutrient competition with the main crops/staples.

2) Agroforestry Planning

The utilization of the available space (interval) between the main trees planted can be optimized with an agroforestry system. This utilization pattern can be done in several steps, including by applying the planting pattern *of alley cropping* and *alternate rows.* In addition, if the community forest area is located in a sloping location, the use of guludan and rorak terraces is an effective step for soil and water conservation. The three crop modifications are then adjusted according to the type of stand and intercropping that are cultivated. The *alley cropping* pattern is land use through a combination of forestry plants and annual plants planted separately on the same land (Figure 3). This is intended so that the growth between plants does not harm each other and can increase growth and productivity. This pattern is also useful for reducing competition for nutrients and water in the soil and making it easier for farmers to clean weeds (Indriani *et al.*, 2024).

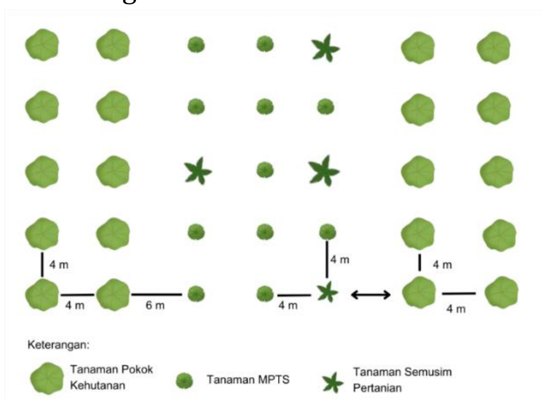


Figure 3. Agroforestry layout with *alley cropping* pattern (modification 1)

The *alley cropping* pattern is recommended by planting forestry plants at the boundaries of the forest area which is applied with a planting distance of 4×4 m then *Multipurpose Tree Species* (MPTS) plants are planted with a distance of 6 meters next to the forestry plants (Figure 3). The distance between MPTS plants is 4×4 m with random planting combined with seasonal agricultural crops. For example, crops that can be combined are gmelina (forestry crops), citrus (MPTS), and peanuts (annual) (Figure 3).

The next utilization pattern is *alternate rows.* This pattern involves planting trees in regular alternating rows and seasonal planting done between rows. This pattern is appropriately used for flat and wide topography (Paudel *et al.*, 2022). This design can be applied to 1 ha of community forest land with a flat topography by planting forestry plants with a planting distance of 4×3 m so that the number of stands that can be planted is 625 stands (land area (m)/planting distance). Annuals or MPTS plants can then be planted between spaces (between) between random planting distances (Figure 4).

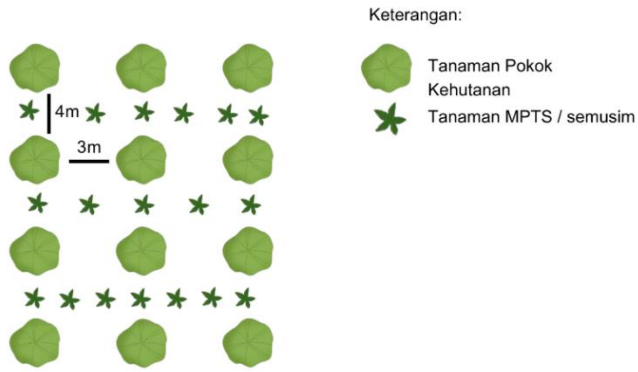


Figure 4. Alternate rows pattern agroforestry layout (modification 2)

According to Paudel *et al*. (2022), the use of *the alternate rows* pattern is an innovation in silviculture technology that is appropriate in areas with limited agricultural land and a high population because it can maximize food production and overcome climate change vulnerability. The existence of the number of annual plants and MPTS plants is a source of food for the community. Forage preparations on existing plants can also be used as animal feed. In addition, soil conditions that are covered by vegetation communities will increase soil fertility because the carbon cycle and nutrient cycle are maintained (Nindya *et al*., 2019).

The agroforestry method that can be developed next is with the pattern of guludan and rorak terraces. The use of guludan and rorak can be used on community forest land located on sloping land (Figure 5). Guludan is a pile of soil that is formed lengthwise along the contour line or cuts a slope, while rorak is an artificial hole that functions to trap and absorb water into the soil.

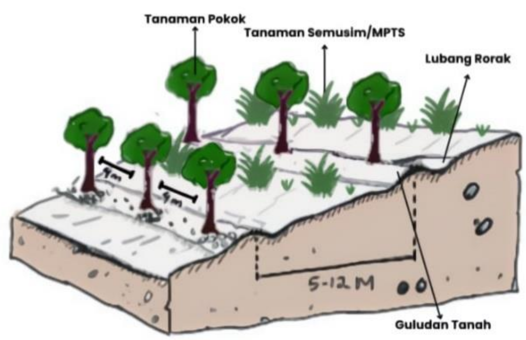


Figure 5. The agroforestry layout is patterned with guludan terraces and rorak on sloping land (Sutopo et al., 2021)

The agroforestry design with this method is made by site manipulation in the form of land clearing from weeds and making stubbles parallel to the contours with a distance of 5-12 meters between stubbles. Rorak was then made in several parts of the guludan. Forestry plants are planted in a row on the lower side of the guludan following the direction of contour alignment with a planting distance of 4×4 m. Annuals or MPTS are planted randomly in the space between forestry plants and guludan (Figure 5). The method applied on sloping land aims to mitigate erosion, conserve soil and water, and increase the productivity of sloping land. The existence of plants managed on sloping land will increase the rate of infiltration in the soil, stabilize soil aggregates, and minimize surface flows that can result in erosion (Hidayat, 2022). This condition will also ensure the availability of organic matter that fertilizes the soil (Lumbantoruan and Sahar, 2021). The flow of water from the rain will also be restrained from the presence of tree canopies and tree trunks, then slowly absorbed into the soil. According to Hidayatullah *et al.* (2022), MPTS commodities are able to provide long-term income from annual crops compared to agricultural crops that have a short term (Appendix 2). This proves the increase in productivity on land located on steep slopes.

3) Selection of Species Trees as Burn Barriers

The fire break *line* has a function as a fire barrier so that the presence of fire does not spread to the surrounding land. The fire barrier can be in the form of a stand (green lane). This line is made with stands that have a clean floor condition from fuel. Plant species that can be used are glycyside *(Glirisidia sepium),* broadleaf mahogany (*Swietenia macrophylla),* gmelina *(Gmelina arborea),* eucalyptus *(Eucalyptus alba),* acacia *(Acacia mangium),* and angsana (*Pterocarpus indicus).* The species was chosen as a burn barrier because it is an evergreen tree and does not shed (*decidous trees*). If the trees chosen are green all year round, the intensity of litter as a fine fuel will be low. According to Setiawan and Rachmawati, (2021), fine fuel in the form of litter dries easily so that if there is direct contact with fire, it will expand the fire area.

The selection of recommended tree species can be used as the main crop because of its economic value. Based on the results of research from Ningrat (2021), harvesting *A. mangium* wood from community forests produces a total income of Rp 5,836,115.22/m3. In addition to ecologically functioning as a combustion bulkhead, *G. sepium* can be used as animal feed (Appendix 2). On an area of 1 ha, if planted *with G. sepium* with a planting distance of 3×3 m, it can produce 15,880 kg/year of leaves and be able to meet the needs of 44 goats (Amin & Junaedi, 2023). Manure produced by livestock can be used as biofertilizer to support soil fertility in community forest land (Attachment 2). Research by Novitasari and Caroline (2021) shows that the quality of goat manure fertilizer has an average value of C-Organic 13.38%, Nitrogen 1.27%, Phosphorus 1.76%, Potassium 1.18%, C/N Ratio 11.85 and moisture content of 35.67% which is beneficial for soil fertility.

Conclusion

Based on the results and discussions, it can be concluded that community forests have significant potential to absorb carbon emissions through the process of photosynthesis. This carbon is stored in the form of biomass, contributing to the production of oxygen and supporting cleaner air. For example, the total biomass of 90.62 tons per hectare in community-managed lands can absorb up to 42.59 tons of carbon per hectare. To enhance this potential, the intensification of silviculture techniques in community forests is carried out by carefully selecting planting distances, designing agroforestry systems, and choosing tree species that serve as fire barriers. The implementation of these silviculture techniques, particularly through the selection of planting distances of 3×4 meters and 4×4 meters, results in optimal tree growth, increased diameter, and improved productivity. Additionally, these planting distances allow for sufficient space to integrate agroforestry practices, which further enhance land productivity without causing harmful competition among plants. Tree species such as Gliricidia sepium, Swietenia macrophylla, Gmelina arborea, Eucalyptus alba, Acacia mangium, and Pterocarpus indicus are particularly effective as fire barriers. These species are evergreen, meaning they do not shed leaves, which reduces the accumulation of litter—an important factor in preventing forest fires. *Gliricidia sepium* is especially valuable as it can serve as both a burn barrier and a source of animal feed due to its nutrient-rich leaves. In light of these findings, the author suggests that further studies are necessary to explore the selection of plant species based on specific site conditions and the preferences of local communities. This will help prevent forest fires and reduce carbon emissions. Additionally, the success of community forest management is largely dependent on the involvement of landowners, meaning that cooperation between various stakeholders is essential to maximizing forest productivity and sustainability.

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