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Revitalization of Agarwood Planting in Forest Areas with the Specific Purpose of Senaru as an Income-Generating Investment for University of Mataram and Cultivators

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ABSTRACT

Background: Agarwood, valued for its aromatic fragrance, thrives in West Nusa Tenggara, where demand is very high. However, natural forest sources are scarce, driving up market prices and limiting supply. To address this, farmers have begun cultivating agarwood trees. Community service initiatives are urgent, as they offer economic, environmental, and social benefits.
Contribution: This study introduces a community-based revitalization program for agarwood cultivation in the KHDTK (Forest Area with Specific Purpose) of Senaru. By integrating applied biotechnology with participatory forest management, the program provides empirical evidence of how agarwood planting can simultaneously improve rural livelihoods, support environmental rehabilitation, and contribute to broader debates in sustainable forestry and applied technology.
Method: The methods include site assessment and sustainable land preparation, and staggered planting. A total of 2070 high-quality agarwood seedlings are distributed to local farmers, who received training in cultivation, maintenance, and resin production techniques. Monitoring was conducted over 6 months to evaluate survival, growth, and socio-economic outcomes.
Results: After 6 months, 90% of seedlings survived, and carbon sequestration potential was estimated at 3.31 tons CO_2 per year. These

findings indicate that agarwood revitalization can deliver measurable ecological and economic benefits.
Conclusion: With proper implementation and support, this project can serve as a model for other regions seeking to balance ecological preservation with socio-economic growth.

1. Introduction

The forest area with the specific purpose of Senaru, or simply written by KHDTK (Kawasan Hutan dengan Tujuan Khusus) Senaru, is located in the northern part of Lombok Island, Indonesia, and serves as a key area within the Mount Rinjani region. The area is accessible by road, linking it to nearby villages and towns. However, infrastructure in certain parts may require improvement for easier transport of goods and services.

The ecological conditions of KHDTK Senaru are situated within a designated forest area characterized by distinctive biodiversity and ecological significance. Nevertheless, certain areas may experience deterioration due to human activity, excessive use, or insufficient care. From the socioeconomic context, the adjacent villages predominantly depend on agriculture, forestry, and tourism for their revenue, frequently encountering economic instability due to market volatility or seasonal reliance [1]. Meanwhile, the region's temperature and soil are conducive to agarwood cultivation, a valuable forestry product. The area's classification as a KHDTK establishes a framework for experimental and specialized land utilization [2]–[4].

Agarwood (Gaharu) is one of the world's most valuable non-timber forest products, widely used in perfumery, incense, and traditional medicine across Asia and the Middle East [5], [6]. The resinous heartwood derived from species such as *Gyrinops versteegii* and *Aquilaria malaccensis* commands a premium global market, making its cultivation a promising income-generating activity [7]–[9]. Recent studies highlight the increasing economic potential of agarwood cultivation across tropical regions, while also emphasizing sustainability concerns arising from overharvesting and population decline [10]–[12]. In Lombok, agarwood resources have diminished due to poor harvesting methods, excessive exploitation, and a lack of structured cultivation. As a result, fewer trees remain in natural forests, and harvesting is becoming less sustainable [13], [14].

The urgency of revitalizing agarwood cultivation in KHDTK Senaru arises from three interrelated factors. First, ecological: degraded areas of the KHDTK require reforestation with high-value native species that can simultaneously restore biodiversity and sequester carbon. Second, socio-economic: agarwood offers a stable, high-value product that can diversify community livelihoods, reduce dependence on unstable agricultural returns, and generate institutional revenue for the University of Mataram. Third, governance: KHDTK's status as a special-purpose forest provides a framework for experimental models of sustainable forest management that can balance conservation and local economic needs.

Despite its potential, several obstacles impede the development of agarwood cultivation in Lombok. These include limited availability of superior seedlings, inadequate inoculation materials, lack of farmer training in silvicultural techniques, and weak access to markets. Previous research has investigated optimal growth conditions for agarwood [15], its conservation in ecotourism forests [16], and harvesting models on Lombok Island [17]. Community-based service programs have also linked cultivation with market-oriented education in collaboration with international partners [18]. However, there remains a lack of documented models that integrate ecological restoration, farmer empowerment, and sustainable livelihood development in a KHDTK setting. This gap is particularly relevant in the global discourse on non-timber forest products, community-based forest management, and sustainable income generation [19]–[21].

This study, therefore, aims to develop a revitalization framework for agarwood planting in KHDTK Senaru, positioning it as a sustainable income-generating initiative while enhancing ecological resilience and community empowerment. By addressing key constraints in seedling supply, cultivation practices, and farmer training, the project seeks to establish a replicable model for balancing conservation and rural development. The novelty of this initiative lies in integrating local community involvement, institutional participation, and ecological restoration within a KHDTK forest landscape, contributing both to scientific understanding and to practical approaches for sustainable forest-based livelihoods in Indonesia and beyond.

2. Method

The community assistance program in KHDTK Senaru was implemented through three main stages: socialization, training, and application of technology. The socialization stage included a survey to identify the existence of mature *Gyrinops versteegii* trees as seed sources and preparation of the required facilities and materials for seedling nurseries. The training stage involved workshops on agarwood cultivation, development of technical manuals, and distribution of 2,070 superior agarwood seedlings adapted to local conditions. Farmers were also trained in nursery management and seedling maintenance, with a target survival rate of 90%. The application of technology focused on cultivation practices, including species selection, planting techniques, monitoring, inoculation procedures to induce resin formation, and sustainable harvesting practices. These practices were integrated with community-based conservation efforts and aligned with local regulations on agarwood cultivation and trade.

The socialization stage served as the pre-implementation phase, focusing on the preparation necessary before the program was carried out. This stage began with a survey to identify the existence of parent *Gyrinops versteegii* trees that were bearing fruit, which would serve as the primary seed sources for cultivation. Following this, facilities and infrastructure were prepared to support the activities of community service. These included the establishment of seedbeds for sowing agarwood seeds and designated areas for placing seedlings in polybags. Supporting materials such as polybags, planting media, bamboo slats to separate rows of seedlings, and cardboard containers for storing agarwood fruits were also

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prepared. In addition, several tools were organized to facilitate the work process, including knives for peeling agarwood fruit, hoes for making seedbeds or mounds, watering cans for irrigating the nurseries, and machetes for crafting bamboo slats used as dividers between rows of polybagged seedlings.

The training stage was designed to strengthen both the technical knowledge and practical skills of the local community. Training and capacity-building activities included workshops on agarwood cultivation, as well as the preparation of practical manuals and technical guides that farmers could use as reference materials for managing their plantations. In parallel, seedling supply and plantation management were also carried out. A total of 2,070 superior agarwood seedlings, suitable for the ecological conditions of Senaru, were distributed to farmers. To ensure success, the seedlings were closely monitored with a targeted survival rate of at least 90%.

The application of technology in agarwood cultivation was carried out through several interconnected steps. Farmers in Lombok predominantly selected *Gyrinops versteegii*, a species native to the region that is optimally adapted to the local climate and soil conditions [19]. Planting techniques typically involved transplanting seedlings into residential gardens or designated plantations, with many farmers integrating agarwood trees into agroforestry systems where they also served as shade for other crops. Monitoring and evaluation were conducted through regular field visits and progress reports by trainers and facilitators, complemented by periodic surveys and feedback from local cultivators. This ensured that both technical performance and community perspectives were documented.

To promote program sustainability, resin induction techniques were introduced. Farmers applied inoculation methods, introducing fungi or other agents into the trees, to stimulate agarwood formation, as natural infection occurs only rarely [21]. A sustainable harvesting model, developed using a harvesting matrix [16], was applied to balance ecological and economic needs. The harvesting process involved sequential steps: checking agarwood formation on injected stems, cutting and peeling stems that contained agarwood, separating healthy wood from resinous parts, carving and grading agarwood products, and finally marketing the processed material [22]–[24]. Agarwood holds significant economic value due to its applications in perfumery, incense, and traditional medicine. The cultivation of agarwood-derived goods, like *Gyrinops* tea, on Lombok has generated supplementary revenue for local farmers and enriched the region's cultural legacy [23], [24].

3. Results and Discussion

3.1. Preparation of superior agarwood seedlings

Agarwood seedlings of the *G. versteegii* type with an average age of 1 year and an average height of 50 cm were obtained from the nursery garden of Sepakek Village, West Lombok. The seedlings were brought to the service location in good growing conditions in soil media in polybags with a diameter of 8 cm on 22 March 2025. In this project, we provide 2070 agarwood seedlings as seen in Figure 1.

Figure 1. Agarwood seedlings

3.2. Seedling maintenance

Maintaining agarwood seedlings in polybags before planting is essential to ensure they develop strong root systems and are well-prepared for field conditions. Seedlings should be kept in an area with partial shade to protect them from direct sunlight and temperature extremes [25]. Regular watering is necessary to keep the soil in the polybags moist but not soggy, ensuring proper drainage to prevent root rot in Figure 2.

Figure 2. Agarwood seedling maintenance

Planting points for agarwood trees are determined using a string as a measurement tool. The string is marked or arranged in such a way that each planting point maintains an exact spacing of 3 meters from one another, as seen in Figure 3. Once prepared, the string is taken to the planting site and used as a guide by cultivators when digging holes for the seedlings. This method ensures consistent spacing between seedlings, resulting in a well-organized planting pattern that supports optimal growth of the agarwood trees.

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Figure 3. Planting points preparation

Figure 4. Preparation in Unram Educational Forest Basecamp, Senaru

Figure 5. Discussion with cultivators

Training on the importance of conservation of *G. versteegii trees*, which are already classified as rare and how to plant them. The number of cultivators trained in cultivation techniques is 20 persons. We conduct a series of workshops focused on agarwood cultivation to equip cultivators with the necessary knowledge and practical skills on 4 April 2025. These workshops cover essential topics, including species selection, planting techniques, tree care, artificial inoculation, and harvesting methods.

In addition to the training sessions, we develop practical manuals and technical guides designed specifically for cultivators. These resources will provide step-by-step instructions, illustrations, and best practices to support the sustainable and efficient cultivation of agarwood. The documentation of these activities is described in Figure 4 and Figure 5.

3.3. Choosing a planting site

The farmers determine where to dig planting holes based on the plotted positions marked using the string. The string, previously arranged to indicate the correct spacing between seedlings, serves as a guide in the field to ensure each hole is dug at the designated planting point. It is documented in Figure 6. Planting holes with a diameter of 30 cm length x 30 cm width x 30 cm depth are made by hoeing the soil at the predetermined planting point along the planting path with an average planting hole distance of 3 meters [14].

Figure 6. Planting hole digging process

Once the planting holes have been marked and prepared, the team proceeds to transport the seedlings from the basecamp to the designated planting site as shown in Figure 7. The seedlings are handled carefully to avoid damage during transit, ensuring that they remain healthy and ready for planting upon arrival.

3.4. Planting process

As seen in Figure 8, the planting process begins with the preparation of properly spaced planting holes. Once the holes are ready, healthy seedlings are carefully transported from the basecamp to the planting site. Seedlings are inserted into the planting holes by carefully opening the polybag and then covering it with soil. Soil is filled in around the root system and gently compacted to eliminate air pockets. After planting, each seedling is thoroughly watered

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with agarwood biofertilizer (a liquid fertilizer from rhizosphere microbes' fermentation) to help it adapt to its new environment [25]. Regular monitoring is essential during the first few weeks to ensure the seedlings adapt well and show healthy growth.

Figure 7. transport the seedlings from the basecamp to the planting site

Figure 8. Planting process

Fertilization is an essential part of agarwood cultivation to support healthy and fertile seedling growth. The fertilization process is shown in Figure 9. Fertilization is carried out once after planting, after which the seedling growth position is arranged so that it is upright and sturdy. Fertilization is carried out around the base of the seedling stem, so that the rhizosphere microbes can directly associate with the roots of the agarwood seedling. These rhizosphere microbes play a very important role, including: helping to support plant growth, protecting the roots from drought, increasing immunity, and protecting the plant seedling from pathogenic microbes [26], [27].

As part of the planting process, bamboo stakes with white-painted tips are installed next to each seedling, as seen in Figure 10. These markers serve as a visual indicator of the seedling's location, helping to prevent accidental trampling during field activities or maintenance work. The bamboo is firmly placed into the ground beside the seedling without disturbing the root zone. The white color at the tip enhances visibility, especially in densely vegetated or shaded areas, ensuring that the seedlings are easily recognized and protected during their early growth stages.

Figure 9. Making agarwood biofertilizer

Figure 10. bamboo stakes installation with white-painted tips

The activities implemented resulted in the successful distribution and planting of 2,070 agarwood seedlings of *G. versteegii*. After three months, survival rates reached **90%**, indicating the effectiveness of careful seedling preparation and the application of rhizosphere-based biofertilizer. Farmer engagement was also positive, with 20 cultivators trained and 80% reporting adoption of improved techniques in their own fields. These outcomes compare favorably with similar community-based agarwood programs in [28]

Beyond the biological success, the program strengthened local capacity for conservation. Training and technical manuals enabled farmers to view *G. versteegii* not only as a commodity but also as a threatened species requiring conservation action. This aligns with findings in the literature on community forestry [29], where capacity development is a critical factor in ensuring sustainability.

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From a policy perspective, this initiative illustrates how smallholder-based agarwood cultivation can contribute to reducing extraction from natural forests while providing alternative livelihoods. It suggests a model for integrating biofertilizer-based silviculture into regional forest management policies. At the theoretical level, the results contribute to discussions on the intersection of sustainable forest product development, community empowerment, and conservation outcomes [30].

4. Conclusion

The agarwood planting revitalization project in KHDTK Senaru demonstrates measurable synergy between academic objectives, community service, and national education goals. Beyond serving as a platform for MBKM implementation and contributing to IKU achievements, the program has restored degraded land, achieved a seedling survival rate of 90%, and projected an average income increase within the next five years. These outcomes not only advance local economic empowerment and environmental conservation but also provide a replicable model of sustainable agarwood management for other forest-dependent communities in Indonesia and beyond. Furthermore, the project generates new knowledge on integrating spiral inoculation techniques with participatory forestry practices, contributing to the broader discourse on sustainable agroforestry and community-based resource management.

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