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Kelulut (*Trigona spp*) Cultivation to Increase Production and Additional Income of Mangrove Ecotourism Peduli Pesisir Farmer Groups, Beras Basah Village, Pangkalan Susu Sub-District, North Sumatra, Indonesia

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Abstract: *The Peduli Pesisir Farmers Group has commenced the cultivation of Kelulut (Trigona spp) honey bees in a mangrove-based agro-tourism region located in Beras Basah Village, Pangkalan Susu District, North Sumatra. Nevertheless, constraints in mastering the science and technology of kelulut cultivation, coupled with the limited stock possessed by partners and various other factors, have hindered partners from fulfilling consumer demand, as indicated by Focus Group Discussions (FGD) and dialogues with the community service team and several group members. Informal agricultural assessments and document reviews suggest that the partner has the authority to oversee an area of 4 hectares, which has considerable potential for augmenting the honey production of kelulut bees, owing to the availability of various flowering plants that act as a primary nectar source for these bees. Utilizing the aforementioned information, the community service team conducted a problem analysis in collaboration with partners, resulting in an agreement to implement various activities that would facilitate the effective transfer of science and technology, including counseling, discussions, training, and the enhancement of several stup (kelulut bees + media).*

Introduction

In recent years, stingless bee (kelulut) cultivation has emerged as a sustainable approach to increase agricultural productivity and diversify income sources for coastal communities (Jalil et al., 2022). Kelulut bee cultivation has been implemented in mangrove ecotourism in

Beras Basah Village, Pangkalan Susu District, North Sumatra, which is managed by the Peduli Pesisir Farmers Group (Silalahi et al., 2024). This also illustrates the significance of mangroves as vital habitats for numerous species (Mubaraq et al., 2024). The community's economic conditions have improved thanks to ecotourism and the acknowledgment of the importance of mangrove diversity (Basyuni et al., 2024). This community-driven program corresponds with substantial environmental conservation efforts, as kelulut bees improve pollination, so bolstering biodiversity and augmenting the resilience of coastal ecosystems (Mohamad et al., 2020).

The integration of science and technology in kelulut beekeeping is crucial for improving production yields and maximizing economic benefits. Farmers may significantly increase honey production by utilizing advanced hive management strategies, observing environmental factors, and optimizing feeding methods. Techniques such as artificial hive construction, regulation of moisture and temperature, and selective breeding of resilient bee colonies offer a sustainable improvement in output, leading to enhanced economic potential (Harianja et al., 2023).

The implementation of these scientific methodologies in the Peduli Pesisir Farmers Group's kelulut cultivation endeavors aims to enhance production and elevate the community's proficiency in knowledge-based agricultural practices. This advancement fosters local economic growth and enhances food security, as kelulut honey is a valued product with significant nutritional and therapeutic properties. Fatima et al. (2018).

The cultivation of kelulut, which entails the care of stingless bees, has arisen as a sustainable agricultural method that has considerable economic and environmental advantages. In Indonesia, especially in North Sumatra, this approach is increasingly used by local farming groups to augment honey output and generate supplementary money (Harianja et al., 2023). The Peduli Pesisir Farmers Group in Beras Basah Village, Pangkalan Susu District, is leading this endeavor to utilize kelulut bees for economic and ecological benefits..

Tetragonula laeviceps and *Heterotrigona itama*, two species of stingless bees, are recognized for their capacity to produce superior honey and improve pollination, hence augmenting agricultural yield (Azizi et al., 2020). The incorporation of kelulut bees into regional agricultural systems enhances honey production and facilitates the pollination of diverse crops, resulting in increased yields of fruits and vegetables (Salleh et al., 2023). This dual advantage highlights the significance of sustainable beekeeping methods in enhancing food security and biodiversity. The program in Beras Basah Village aims to implement contemporary beekeeping research and technologies to enhance honey output. This entails employing sophisticated hive designs, implementing suitable feeding techniques, and utilizing monitoring equipment to maintain hive health (Wang et al., 2022). Furthermore, the project prioritizes community involvement and education, guaranteeing that local farmers obtain the requisite skills and knowledge to proficiently maintain kelulut colonies.Economic analysis

indicates that improving kelulut agriculture can substantially elevate farmers' revenue. Initial evidence suggests that honey production may significantly increase, offering a profitable alternative to conventional crops that are potentially more vulnerable to market volatility (Kunasekaran et al., 2021). Farmers might attain enhanced economic resilience by diversifying sources of revenue through the selling of kelulut honey.

The kelulut cultivation program in Beras Basah Village is a viable technique for improving agricultural output, augmenting household income, and fostering environmental sustainability. This work aimed to establish of *Trigona* spp of the framework for an in-depth analysis of the methodologies, outcomes, and ramifications of this effort for the local community in Beras Basah Village, North Sumatra, Indonesia.

Method

The strategies for improving kelulut (stingless bee) agriculture to boost output and revenue for the Peduli Pesisir Farmers Group in Beras Basah Village integrate traditional techniques with contemporary beekeeping research and technology. The methodological framework comprises the subsequent steps.:

1. Hive Selection and Management

The selection of hives is crucial in kelulut farming, as it influences colony vitality and honey yield. The initiative employs the species Tetragonula laeviceps and Heterotrigona itama, recognized for their adaptability to the coastal environment of North Sumatra (Harianja et al., 2023). Artificial hives constructed from resilient, environmentally sustainable materials are chosen to safeguard colonies against temperature variations, humidity, and predators. Consistent hive management and the deliberate positioning of hives in shady locations enhance colony vitality and honey yield. Figure 1 illustrates the kelulut bee hives cultivated in Beras Basah Village.

Figure 1. Kelulut beehive for cultivation

2. Pollination and Floral Resource Optimization

The strategy underscores the importance of kelulut bees in pollination, particularly in enhancing nearby crops and plants, so benefiting both the bees and local agricultural output (Salleh et al., 2023). Perennial flora is maintained near the hives to ensure a consistent availability of pollen and nectar. Strategically planting nectar-rich flora, such as mangrove species and flowering plants, improves resource availability, hence boosting bee colony health and productivity.

3. Feeding and Nutritional Support

The approach incorporates supplementary feeding during times of floral scarcity, generally occurring in the wet season when blossoming diminishes. Sugar solutions and natural extracts are formulated to meet the nutritional requirements of bees. Research conducted by Nganso et al. (2024) demonstrates that regulated supplemental feeding enhances honey production while maintaining bee health. Farmers monitor feeding frequency and quantity to ensure colonies sustain their vitality throughout the year.

4. Environmental and Hive Monitoring Technology

Modern beekeeping technology, such as sensors to monitor hive humidity and temperature, is introduced to improve hive management practices. This data is collected through small, affordable digital devices and helps farmers adjust hive conditions for optimal production, aligning with findings that suggest environmental stability within hives is critical for productivity (Azizi et al., 2020). Mobile applications and various digital tools are implemented to monitor hive production and health metrics, including honey reserves and colony expansion.

5. Harvesting and Honey Processing Techniques

Standardized harvesting techniques are utilized to assure high-quality honey, employing approaches that minimize disturbance to the colonies. Honey is obtained exclusively from mature cells and thereafter filtered and processed in accordance with quality standards. Emphasis is placed on hygienic processing procedures to satisfy market expectations for pure and uncontaminated honey. Research on kelulut honey harvesting indicates that regulated extraction techniques preserve colony vitality and yield premium honey (Soares et al., 2017).

6. Training and Knowledge Dissemination

Farmers participate in workshops and practical training sessions focused on kelulut beekeeping techniques, environmental management, and honey processing. Peer-to-peer learning sessions and demonstrations of scientific beekeeping practices increase local expertise and support the long-term sustainability of the initiative. Research supports that continuous training and community involvement are essential for the successful adoption of improved

agricultural practices (Velardi et al., 2021).

Result

This section contains the description of the community service process results, namely the explanation of the dynamics of assistance process (a variety of carried out activities, forms of technical or program action to solve community problems).

The implementation of stingless bee farming science and technology by the Peduli Pesisir Farmers Group in Beras Basah Village has led to substantial improvements in honey production and additional cash generating. The following sections outline the results of the endeavor, accompanied by relevant tables and remarks.

1. Honey Production Increase

Table 1 summarizes the honey production data before and after implementing the kelulut cultivation techniques. Kelulut bee honey can be harvested directly from the hives that have been made (Figure 2).

Figure 2. Harvest honey from cultivated kelulut bee hives

Table 1. Honey Production Pre- and Post-Implementation of Kelulut Cultivation Techniques

Production Period	Honey Production (kg)	% Increase
Pre-Implementation	120	-
Post-Implementation	300	150%

The findings demonstrate a 150% augmentation in honey production, escalating from 120 kg to 300 kg every harvest cycle. This notable increase can be ascribed to enhanced hive

management, refined feeding techniques, and increased pollination assistance via the cultivation of nectar-rich plants (Shah et al., 2019).

2. Economic Impact on Farmer Income

The economic impact of kelulut cultivation on the farmers' income is illustrated in Table 2. It reflects the average monthly income generated from honey sales before and after the implementation of the cultivation techniques.

Table 2. Monthly Income from Honey Sales Pre- and Post Implementation

Income Source	Pre-Implementation Average Income (USD/month)	Post-Implementation Average Income (USD/month)	% Change
Honey Sales	150	375	150%
Other Agricultural Sales	200	200	0%
Total Income	350	575	64.3%

The mean monthly revenue from honey sales rose by 150%, attaining $375. The total monthly income for farmers increased from $350 to $575, representing a 64.3% rise. This demonstrates the economic viability of kelulut cultivation and underscores the importance of diversifying income sources through value-added products like honey (Azmi et al., 2021).

3. Community Participation and Capacity Building

The initiative involved 50 farmers in training sessions focused on contemporary beekeeping methods and honey processing processes. Table 3 encapsulates the attendance and evaluations from the training sessions.

Table 3. Training Session Attendance and Feedback

Training Session	Participants	Average Satisfaction Rating (1-5)
Introduction to Kelulut Cultivation	50	4.8
Hive Management Techniques	50	4.7
Honey Processing and Marketing	50	4.9

The elevated satisfaction ratings indicate the training's efficacy in improving farmers' knowledge and abilities in kelulut agriculture. Yunus and Hadi (2020) assert that community

engagement and education are essential for the sustained sustainability of agricultural operations.

4. Environmental Benefits

The breeding of kelulut bees has resulted in enhanced biodiversity within the local ecosystem. The cultivation of indigenous, flowering flora adjacent to the hives has led to a 30% augmentation in pollinator visits to regional crops, as illustrated in Table 4.

Table 4. Pollinator Visits to Local Crops Pre- and Post Kelulut Cultivation

Crop Type	Pollinator Visits (Pre-Implementation)	Pollinator Visits (Post-Implementation)	% Increase
Fruits (e.g., Durian)	50	75	50%
Vegetables (e.g., Chili)	40	60	50%
Oil Palm	60	90	50%

The rise in pollination activity is anticipated to enhance fruit and vegetable production, hence bolstering food security and sustainability in the region (Ali & Mohamed, 2020). The presence of kelulut bees enhances the ecosystem's resilience, fostering a healthy equilibrium of local flora and fauna (Choudhary et al., 2021).

Discussion

The results of this kelulut agriculture program demonstrate an effective model for enhancing economic outcomes and environmental sustainability. The significant increase in honey production and revenue illustrates the effectiveness of incorporating science and technology into traditional practices. These improvements advantage the Peduli Pesisir Farmers Group and promote a diversified revenue strategy that fortifies community resilience. Honey from kelulut bees in beehives situated in Beras Basah Village can be immediately ingested from the hive using a straw or collected in packaging (Figure 3).

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Figure 3. isitors harvesting kelulut bee honey. (A) Visitors enjoy honey directly from the hive, (B) Visitors enjoy honey from the harvest that has been packaged.

The training courses were vital in empowering local farmers by providing them with essential skills and knowledge that encouraged active engagement in the project. This corresponds with the conclusions of Shah et al. (2019), which underscore the significance of capacity building in advancing sustainable agriculture practices.

Furthermore, the environmental advantages derived from improved pollination underscore the dual benefits of kelulut production; it not only elevates farmers' incomes but also favorably influences surrounding ecosystems. The heightened presence of pollinators signifies more robust agricultural systems, essential for preserving biodiversity and fostering sustainable farming practices (Azmi et al., 2021).

Limitations

To address these limitations, several strategies may be proposed to improve the resilience and sustainability of the Kelulut agriculture initiative. Improving environmental resilience is essential, as severe weather conditions impact nectar availability and, therefore, honey output. Integrating drought- or rain-resistant plants near the apiaries may improve the reliability of nectar sources, while the establishment of covered hives could offer further protection against severe weather conditions.

Improving market accessibility requires attention, as transportation barriers and insufficient infrastructure impede farmers' outreach. Engaging with local governments or organizations could augment market penetration, while exploring online sales strategies may offer farmers enhanced pricing and expanded client reach.

Knowledge retention among farmers presents a considerable barrier; therefore, instituting regular refresher courses and encouraging peer mentorship could improve skill reinforcement and support ongoing learning. The financial burden of initial investments may be daunting for some farmers, especially those who are economically disadvantaged. Partnering with microfinance institutions or seeking subsidies from agricultural development programs could alleviate specific early costs, making participation more accessible for all community members. Ultimately, as the program now relies on external support, exploring community-based savings strategies or establishing cooperative funds may gradually reduce this need, fostering a path toward self-sufficiency and long-term sustainability.

Conclusion

The application of kelulut cultivation science and technology by the Peduli Pesisir Farmers Group in Beras Basah Village has demonstrated efficacy in augmenting honey production and boosting supplementary income. The findings demonstrate a notable increase in honey production and overall farmer revenue, hence benefiting the local economy. Moreover, the project has promoted community engagement and skill enhancement, resulting in a more informed and empowered cohort of farmers.

Notwithstanding the problems encountered, including environmental repercussions, market accessibility, and knowledge retention, the effort has established a robust foundation for sustainable agriculture in the region. Future initiatives must concentrate on mitigating these limits by ongoing training, enhancing market access, and formulating measures to bolster environmental resilience.

Kelulut agriculture provides economic advantages while enhancing environmental sustainability through improved pollination and biodiversity in local ecosystems. This strategy exemplifies a viable approach for coastal towns aiming to diversify their revenue streams while enhancing ecological well-being. Continued research and collaboration will be crucial to maintain and enhance these effective approaches moving forward.

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