



## The Potential of Aquatic Eco-Tourism and Agroforestry in the Sustainable Management of the Duma Galela Volcanic Lake Area, North Halmahera

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### ABSTRACT

One of the volcanic lakes in Galela District, North Halmahera Regency, known as the "Lake Area" or "Talaga Duma" has great potential to develop water-based natural tourism through the concept of aquatic eco-tourism and agroforestry. Its beauty and incredible biodiversity make the area suitable for the development of these two industries, which can help preserve the environment and grow the local economy. The purpose of this study is to evaluate the potential of water ecotourism and agroforestry in sustainable area management. The study was conducted qualitatively and quantitatively, and data were collected through interviews with stakeholders and the community, field observations, and analysis of related literature. The results of the study show that aquatic ecology tourism in Lake Duma Galela can be a major attraction due to activities such as sustainable fishing and water conservation training that support the preservation of ecosystems and biodiversity. Despite this, agroforestry has been proven to improve people's food security and economy by combining forestry and environmentally friendly agriculture. However, limited infrastructure and lack of public knowledge of sustainability principles are issues that hinder the growth of these two sectors. In summary, the development of ecological and agroforestry tourism in Lake Duma Galela has great potential to support the local economy and nature conservation. However, to achieve long-term sustainability, this requires a more integrated and cooperative approach.

### INTRODUCTION

The Duma Galela Lake Volcanic Lake area, located in North Halmahera Regency, North Maluku Province, is one of the natural places with a lot of potential to

develop tourism, especially in terms of water ecotourism and agroforestry. Lake Duma Galela is not only known as a volcanic lake rich in natural resources, but also has great potential to combine sustainability ideas through two important industries, namely fishery-based eco-tourism and agroforestry that focuses on environmental conservation and local community empowerment (**Sulistiyadi *et al.*, 2024**). Conserving biodiversity and ecosystems, especially in the Indonesian archipelago which is rich in maritime potential (**Hermawan *et al.*, 2023**) is important. Conservation efforts are increasingly aware of the importance of historical ecology and biocultural relationships in shaping local conservation activities (**Soselisa & Ellen, 2024**).

Sustainable economic development, nature-based tourism potential in the region is very important, especially in the fisheries and agroforestry sectors (**Nurdin *et al.*, 2020**). Water ecology tourism includes the exploration and utilization of aquatic ecosystems for recreation, education, and conservation. This ecological tourism can have a positive impact on the local economy and environmental awareness of the surrounding community (**Nurdin & Saelan, 2020**). In addition, a land-use system called agroforestry combines fishery crops with trees and other vegetation to maintain biodiversity, reduce the effects of erosion, and improve people's food and economic security. Such nuanced understanding is critical to implementing sustainable agroforestry ecosystems, which integrate ecological, economic, and sociocultural dimensions (**Di & Liu, 2024**). Therefore, an integrated spatial planning model that prioritizes conservation and utilization of local communities is essential to optimize resource management in ecologically sensitive areas such as Duma Galela (**Darmawan *et al.*, 2025**).

Lake Galela, as one of the largest volcanic lakes in North Maluku, faces serious challenges related to the decline in water quality due to anthropogenic activities such as cage fish farming, capture fisheries, and tourist attractions. Decreased fish production due to fluctuations in water quality and sedimentation has become a serious concern in volcanic lakes (**Kaban *et al.*, 2023**). A holistic approach that integrates sustainable fisheries and agroforestry is needed, taking into account water quality and ecosystem sustainability (**Sudarmadji *et al.*, 2019**; **Kaban *et al.*, 2023**). Implementing sustainable fisheries management and promoting environmentally friendly aquaculture practices are essential (**Rolland *et al.*, 2022**). Applying the green economy concept, such as using fish feed filters in floating net cages, helps maintain lake water quality (**Nuringtyas *et al.*, 2023**). The sustainable management of lake ecosystems relies heavily on active community participation and must consider all aspects—physical and non-physical—including economic, ecological, social, cultural, and institutional factors to achieve long-term sustainability (**Parsaulian *et al.*, 2023**).

This integrated approach is essential to reduce threats to biodiversity, such as those arising from population growth, deforestation, agricultural land conversion, natural disasters (**Dissanayaka *et al.*, 2023**). In this context, understanding the socio-cultural,

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environmental, and economic factors that influence local small-scale farming systems becomes essential to assess their ecological sustainability (**Taylor *et al.*, 2025**). The research problem is how to investigate the prospects and problems related to the development of aquatic eco-tourism and agroforestry in the Volcanic Lake area of Duma Galela Lake. The purpose of this study is to study and analyze the potential and obstacles of the growth of aquatic eco-tourism and agroforestry in the volcanic lake area of Lake Duma Galela that benefits local communities while maintaining nature conservation.

### **MATERIALS AND METHODS**

#### **a. Research location and time**

This research was conducted in the Duma Galela volcanic lake area, which is located in North Halmahera Regency, North Maluku Province. This area was chosen because it has great potential in the development of aquatic eco-tourism and agroforestry as well as a unique ecosystem status and is important for environmental conservation. The research time is July – November 2024.

#### **b. Research approach**

This study used a mixed-methods approach, which allows for more complete data collection and analysis. This approach was chosen to explore the economic, social, and environmental potential of aquatic eco-tourism and agroforestry holistically. The qualitative approach provides in-depth insights into public and stakeholder perceptions of the two sectors, while the quantitative approach provides measurable data on economic, social, and environmental impacts.

#### **c. Data collection techniques**

Data were collected using several techniques to obtain a comprehensive picture of the potential of the two sectors:

- **Quantitative Survey:** The survey was conducted to collect data on the number of tourist visitors, the number of fishing activities, income from the tourism sector, as well as the area of agroforestry, agroforestry product production, and income from agroforestry. This survey was conducted using questionnaires distributed to visitors and local business actors, such as tour guides, farmers, and fisheries managers.
- **In-depth Interviews:** Interviews were conducted with key stakeholders, such as local governments, fisheries sector managers, agroforestry farmers, tourism entrepreneurs, and local communities. This interview aimed to explore their

perceptions of the potential and challenges of the development of aquatic eco-tourism and agroforestry, as well as their impact on the local economy and environmental conservation.

- **Focus Group Discussions (FGD):** The FGD was conducted with local community groups, farmer groups, and tourism business actors to discuss the opportunities and challenges faced in developing the two sectors, as well as to obtain a common view on the sustainability of regional management.
- **Field Observation:** The researcher conducted direct observation of tourism, fishing, and agroforestry practices applied in the Duma Galela Lake area. These observations help understand management dynamics, as well as identifying problems and potentials in the field.

#### **d. Data analysis**

- **Quantitative Analysis:** Data from quantitative surveys were analyzed using descriptive statistics to describe the demographic characteristics of visitors, the number of fishing activities, tourism sector income, and the area of agroforestry area, production, and agroforestry income. This analysis provided an overview of the contribution of the two sectors to the local economy and regional management.
- **Qualitative Analysis:** Interview data and FGD were analyzed with a thematic analysis approach to identify the main themes that emerge related to the potential and challenges in the development of aquatic eco-tourism and agroforestry. This analysis was used to explore public perceptions and experiences regarding the impact of the two sectors on environmental sustainability and local economic empowerment.
- **SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis:** This method was used to analyze the strengths, weaknesses, opportunities, and threats related to the development of aquatic eco-tourism and agroforestry in the Duma Galela Lake area. This analysis will provide a more strategic view of the steps that need to be taken to increase the potential of the two sectors.

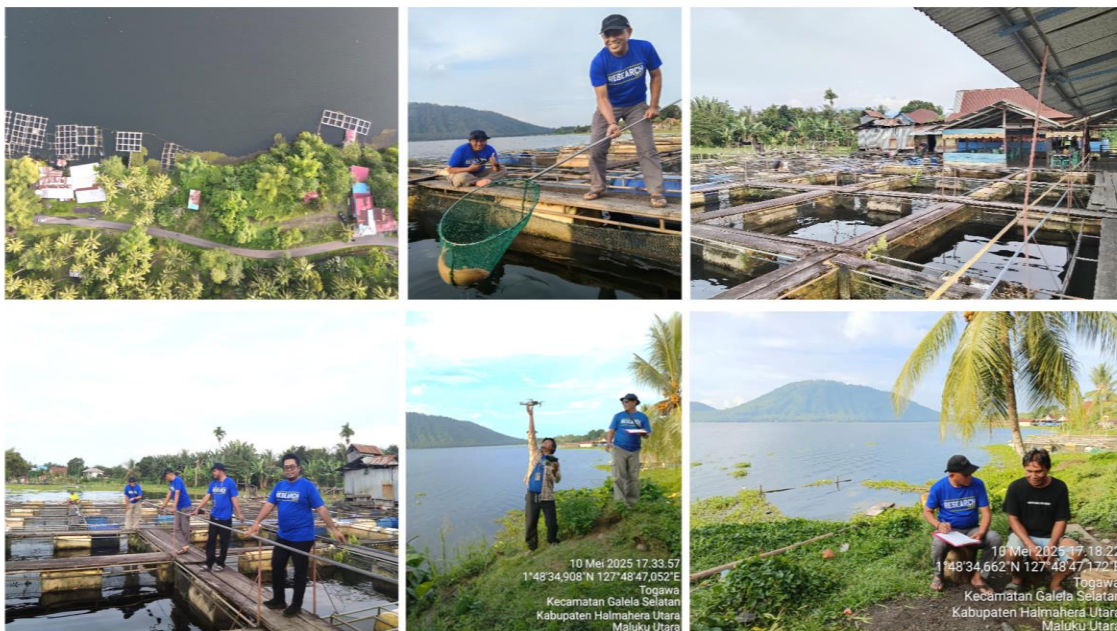
## **RESULTS AND DISCUSSION**

### **A. The potential of the Dum Galela Lake area**

The Duma Galela Lake aquatic eco-tourism area is one of the leading destinations in North Halmahera that unites natural beauty and economic potential through inland fisheries cultivation activities. Based on Fig. (1), this area displays a wide lake view with green hills and the use of water areas for floating net ponds (KJA). Community activities

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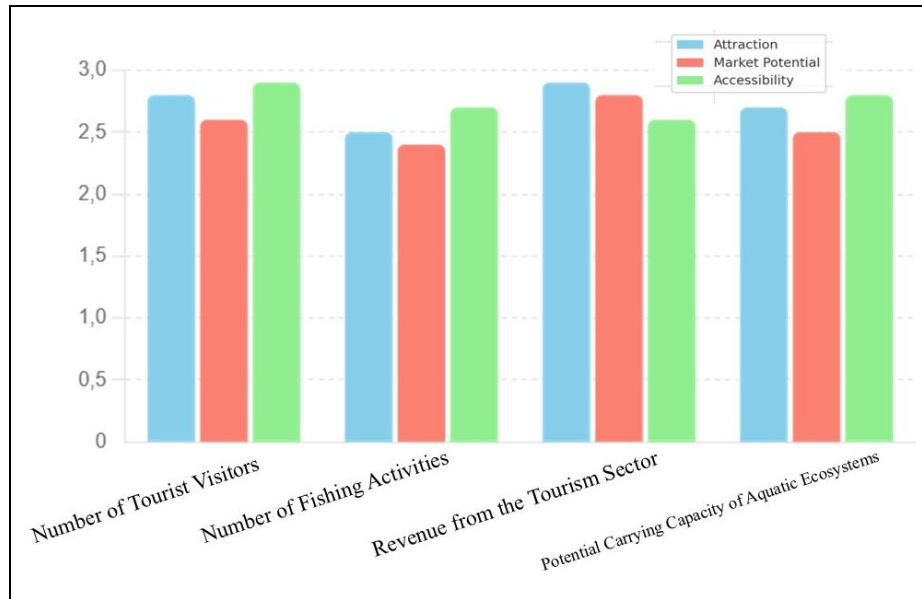
seem to be focused on the cultivation of freshwater fish such as goldfish, tilapia, and mujair, which are the main commodities of local fisheries. The existence of a neatly arranged KJA shows a fairly good management system, while supporting the economy of the surrounding community. In addition, simple facilities such as gazebos, lakeside food stalls, and recreational areas add to the attraction of nature-based and educational tourism. The beauty of the panorama and the coolness of the surrounding air make this area very potential to be developed as a sustainable aquatic ecotourism tourism. With proper management, Lake Duma Galela not only functions as a center for fish production but also as a tourist space that introduces the concept of ecotourism based on conservation and empowerment of local communities, where tourism, fisheries, and environmental conservation activities go hand in hand.



**Fig. 1.** Conditions of the aquatic eco-tourism area in Lake Duma Galela

### B. Fisheries and eco-tourism potential

Fig. (2) shows the characteristics of aquatic eco-tourism in the Duma Galela volcanic lake area, focusing on three main aspects: Attraction, market potential, and accessibility, which are assessed on a scale of 1 to 3. Each category is measured on a scale that describes the extent to which the sector meets expectations from the perspective of tourist attraction, market potential, and ease of access.



**Fig. 2.** Characteristics of aquatic eco-tourism in the Duma Galela volcanic lake area

### 1. Number of tourist visitors

From the graph, the number of tourist visitors category shows a relatively balanced value between the three aspects measured. The attraction reached a score of 2.8, indicating that this lake has a fairly high attraction for tourists, both local, domestic, and international. The market potential is at a score of 2.6, which signifies good market potential, although there is still room to increase market penetration further. Accessibility is slightly higher with a value of 2.9, which indicates that the area is quite accessible to tourists, although there are still challenges related to infrastructure that need to be improved.

### 2. Number of fishing activities

In the category of the number of fishing activities, attraction and market potential almost identical scores, 2.7 and 2.5, were respectively determined. This shows that fishing as the main tourist activity has good appeal, although its market potential can still be expanded further. Accessibility is slightly lower at 2.4, indicating that while there is interest in fishing activities, there may be some access constraints to the location that need to be addressed.

### 3. Revenue from the tourism sector

For the revenue from the tourism sector category, attraction remained ahead with a score of 2.9, which shows that this sector has great potential to generate revenue. The market potential is at 2.7, confirming the opportunity to increase revenue further.

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Accessibility received a score of 2.8, indicating that while the sector is well reached, some improvements in transportation access can increase revenue more significantly.

#### **4. Potential carrying capacity of aquatic ecosystems**

The category of carrying potential of aquatic ecosystems shows a high score for attraction (3.0), which indicates that the quality of aquatic ecosystems is the main attraction for tourists and conservationists. The market potential and accessibility obtained scores of 2.5 and 2.6, respectively, indicating greater potential to improve management and accessibility to support further development. The potential of fisheries and eco-tourism in the volcanic lake area of Lake Duma Galela, North Halmahera is presented in Table (1).

**Table 1.** Data on fisheries and eco-tourism potential in the volcanic lake area of Lake Duma Galela, North Maluku

| <b>Category</b>                                   | <b>Local</b> | <b>Domestic</b> | <b>International</b> | <b>Total</b> |
|---------------------------------------------------|--------------|-----------------|----------------------|--------------|
| Number of Tourist Visitors                        | 3120         | 1230            | 200                  | 4550         |
| Number of Fishing Activities                      | 110          | 60              | 10                   | 180          |
| Revenue from the Tourism Sector                   | 5000000      | 3000000         | 2000000              | 10000000     |
| Potential Carrying Capacity of Aquatic Ecosystems | 1570         | 1210            | 120                  | 2900         |

Source: Data processed in 2025.

The potential of fisheries and natural tourism in the volcanic lake area of Lake Duma Galela, quantitative data analysis, displayed in the form of tables, provides in-depth insights into the potential of this region for the growth of the nature-based tourism sector, especially aquatic ecological tourism. Four main elements are discussed in Table (1) consisting of the number of tourists, the number of fishing activities, income from tourism, and the possible carrying capacity of aquatic ecosystems. These data are important to determine the potential of Lake Duma Galela as a sustainable tourist destination from an economic and environmental perspective.

##### ***a. Number of tourist visitors***

Table (1) shows the number of tourist visitors including local, domestic, and international tourists. It consists of 3,120 local visitors, 1,230 domestic tourists, and 200 international tourists. There were 4,550 visitors. This graph of the number of visitors shows that the majority of visitors are local and domestic. Although Lake Duma Galela is

more visited by local or domestic tourists, the potential to attract foreign tourists is still there. These data are essential for planning further infrastructure development and promotion to attract foreign tourists.

***b. Number of fishing activities***

One of the main attractions of water tourism and ecotourism in the Duma Galela Lake area is fishing. Table (1) shows the number of fishing activities as many as 180. The types of fish caught during this activity were also recorded, especially endemic fish types that are very important for conservation. There are also catch-and-release events, where caught fish are released back into the waters to keep the fish population alive. As the graph on the number of fishing activities shows, more and more tourists are interested in fishing in this area. However, it is important to ensure that this fishing is carried out in a sustainable manner so as not to damage the aquatic ecosystem.

***c. Tourism revenue***

Table (1) shows that water ecological tourism activities in the region generate income. Admission tickets, tour guides, fishing equipment rentals, and other services earn 10,000,000 IDR. Fig. (1) shows the structuring of the concept of aquaculture shows that tourist interest can play a significant role in the local economy. The largest expenditure comes from the rental of equipment and tour guides, indicating that visitors prefer to use services offered by professionals. This not only allows the growth of micro, small, and medium enterprises (MSMEs) that depend on nature tourism services, but it can also provide employment for local communities.

***d. Power potential to support water ecosystems***

In addition, this study analyzed the capacity of the aquatic ecosystem of Lake Duma Galela to function. Table (1) shows that the region has a good capacity to support tourism and fisheries without damaging the ecosystem. With stable fish numbers and maintained water quality, the region has a very high carrying capacity, which is very important for the sustainability of this business. Images showing this potential carrying capacity show that this area can support sustainable natural tourism with careful management. Existing biodiversity, both flora and fauna, is very important to evaluate the success of ecosystem management, as well as its carrying capacity for tourism and fisheries activities.

## **5. Agroforestry potential**

The Lake Duma Galela agroforestry area shows a strong synergy between nature and sustainability-based agricultural and fishery activities. In the first image, it appears that community activities are being discussed, perhaps regarding land management or local agricultural programs, which reflect the active involvement of the community in environmental conservation. In the second image, a sprawl of plants is seen thriving

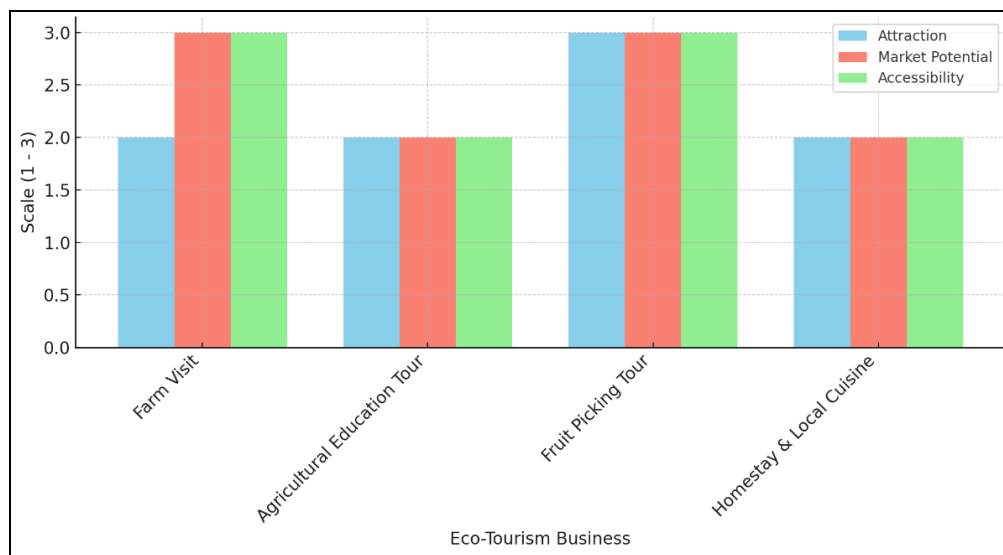
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along the edge of the lake, possibly including crops that can support agroforestry systems, such as coconut, coffee, or nutmeg, which are local commodities.



**Fig. 3.** Agroforestry area of volcanic Lake Duma Galela Lake, North Maluku

The existence of this plant not only serves as an economic booster, but also as a soil erosion inhibitor which is important for maintaining the quality of the environment around the lake. The third image shows the floating net pond (KJA) area adjacent to the agroforestry system, showing how the community uses the potential of land and waters in an integrated manner. Agroforestry in this region provides opportunities for farmers and fishermen to reap the dual benefits of both agricultural and aquaculture products, as well as contributing to nature conservation. With the right approach, this area has the potential to become a superior example for sustainable natural resource management.



**Fig 4.** Characteristics of agroforestry potential in the Duma Galela Lake area

Based on the graph displayed, we can see the characteristics of agroforestry-based eco-tourism products and leading businesses in the volcanic lake area in North Maluku. This graph measures three important dimensions for each eco-tourism product tested, namely attraction, market potential, and accessibility, on a rating scale of 1 to 3.

### **1. Farm visit**

On farm visit, this product shows a relatively balanced value between attraction (2.8), market potential (2.7), and accessibility (2.9). This shows that visits to local farms have a fairly high appeal, and a good market potential, and are easily accessible to tourists. These activities tend to appeal to tourists interested in rural activities and hands-on interaction with nature, offering an educational and relaxation experience.

### **2. Agricultural education tour**

For the agricultural education tour, the graph shows slightly lower values, with attraction at 2.4, market potential at 2.5, and accessibility at 2.3. While it has the potential for education and insight for visitors, its appeal value is slightly lower compared to other products. This can be due to a lack of promotion or limited accessibility for tourists to participate in such educational programs.

### **3. Fruit picking tour**

Fruit picking tour showed the highest score among other products, with attraction and market potential of 2.9 and 2.8, respectively, and accessibility of 2.7. This shows that fruit picking activities are very attractive to tourists and have great market potential. Its high accessibility allows many tourists to experience it, and this greatly supports the development of agroforestry-based tourism products.

### **4. Homestay & local cuisine**

Lastly, homestay & local cuisine had slightly lower scores for attraction and market potential, at 2.4 and 2.6, respectively, with accessibility reaching 2.5. This shows that while it offers a unique local cultural experience, it has challenges in attracting tourists and developing its maximum market potential.

Overall, this graph provides valuable insights into the most potential agroforestry-based eco-tourism products in the volcanic lake region, which can serve as the basis for further development strategies, including increased accessibility and promotion for less attractive products. Table (2) shows the potential of agroforestry to support environmental conservation and economic sustainability in the Duma Galela volcanic lake region. These data include four important components: the area of agroforestry, the production of agroforestry products, agroforestry income, and the biodiversity of the region. All of these elements are interconnected and show how agroforestry can help sustainable development by combining forestry, agriculture, and nature conservation.

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**Table 2.** Agroforestry data in the volcanic lake area of Lake Duma Galela, North Maluku

| Category                            | Fruit Plants | Forestry Crops | Medicinal Plants |
|-------------------------------------|--------------|----------------|------------------|
| Agroforestry Area Area              | 400          | 500            | 110              |
| Production of Agroforestry Products | 1500         | 2000           | 200              |
| Income from Agroforestry            | 2000000      | 3500000        | 1000000          |
| Biodiversity in Agroforestry        | 12           | 35             | 7                |

Source: Data processed in 2025.

**a. Area of agroforestry area**

The agroforestry area around Lake Duma Galela was the first area discussed. The agroforestry area reaches 1,000 hectares, with different types of crops grown: fruit crops, forestry crops, and medicinal crops. The area is 400 hectares of fruit crops, 500 hectares of forestry crops, and 110 hectares of medicinal crops. Graphs showing the area of agroforestry show a balanced distribution, with the majority of the area consisting of fruit crops and forestry plants. This shows that this type of plant is very economically profitable and helps soil conservation and biodiversity. It is important to determine how much agroforestry systems can be implemented in the region and how they can help conserve land and prevent erosion.

**b. Production of agroforestry products**

The data further discuss agroforestry outcomes, which include products from all three types of crops grown: wood, fruit, and medicinal plants. The production of agroforestry products totals 8,500 tons. The largest production is 5,000 tons of forestry plants, followed by 3,000 tons of fruit crops and 500 tons of medicinal plants. Timber products, which have great potential for local and international markets, dominate the production of agroforestry products, as shown in the graph depicting the production of agroforestry products. With a significant production contribution, fruit crops show the market potential of agricultural products. Medicinal plants have a high added value, especially in the local market and for household consumption, although their production is smaller.

**c. Income from agroforestry**

The income generated from agroforestry is an important indicator to assess how effectively the agroforestry system helps the local economy. According to this study, agroforestry generates 6,500,000 IDR. Agroforestry products are sold to local and

international markets, which generate this income. Among these sources of income are fruit plant products, wood, and medicine. Medicinal plants still provide more income for local communities, although their contribution is smaller than forestry and fruit crops. This income graph shows that agroforestry can help communities around Lake Duma Galela earn sustainable income while reducing their dependence on other unsustainable industries.

***d. Biodiversity in agroforestry***

The biodiversity derived from sustainable agricultural and forestry systems is the most important component of agroforestry. The biodiversity of Lake Duma Galela includes 45 species of animals and plants. The plants and trees grown in these agroforestry systems not only make money but also provide a place for various species to live, increasing the biodiversity of the area. The high biodiversity shows that this agroforestry successfully combines elements of nature conservation and agriculture, creating an economically advantageous system and helping nature conservation. Graphs showing biodiversity show that the agroforestry area around Lake Duma Galela helps the sustainability of the ecosystem and produces many agricultural products.

***C. SWOT analysis***

Duma Galela Lake in North Halmahera has great potential for the development of water-based ecotourism and agroforestry. As the largest freshwater lake on Halmahera Island, this lake offers alluring natural beauty, with crystal clear waters and an environment that supports natural tourism activities such as boating, fishing, and swimming. In terms of agroforestry, the area around the lake is dominated by coconut, palm, and banana plants, which can be used for sustainable agroforestry systems. The combination of ecotourism and agroforestry can increase the income of local communities and support environmental conservation. However, it is important to address the issue of land degradation and land-use changes that can affect the sustainability of both sectors.

Overall, the development of ecotourism and agroforestry in Lake Duma Galela has significant potential, but requires a careful and collaborative approach between governments, communities, and other relevant parties to ensure sustainability and shared prosperity. In the SWOT analysis of the potential for aquatic eco-tourism and agroforestry development in the Duma Galela Lake area, North Halmahera is presented in Table (3).

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**Table 3.** SWOT analysis of the potential development of aquatic eco-tourism and agroforestry in the Duma Galela Lake area, North Halmahera

| <b>Category</b>      | <b>Aquatic Eco-Tourism</b>                                                                                                                                                                                                                                                                                                         | <b>Agroforestry</b>                                                                                                                                                                                                                                                                                                                                        |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Strengths</b>     | <ul style="list-style-type: none"> <li>- High biodiversity</li> <li>- The natural beauty of the volcanic lake that attracts tourists</li> <li>- Support from local government</li> <li>- Sustainable approach to conservation and community empowerment</li> </ul>                                                                 | <ul style="list-style-type: none"> <li>- Plant diversity that can support agriculture and forestry</li> <li>- Improving food security and local economies</li> <li>- Provide habitat for local fauna and support environmental conservation</li> <li>- Market potential of agroforestry products</li> </ul>                                                |
| <b>Weaknesses</b>    | <ul style="list-style-type: none"> <li>- Limited infrastructure (road access, accommodation)</li> <li>- Limited human resources in tourism and conservation management</li> <li>- Dependence on seasons and weather that can affect tourism and fishing activities</li> </ul>                                                      | <ul style="list-style-type: none"> <li>- Limited infrastructure in agroforestry areas</li> <li>- Lack of training for communities in sustainable agroforestry management</li> <li>- Dependence on weather conditions and climate change</li> </ul>                                                                                                         |
| <b>Opportunities</b> | <ul style="list-style-type: none"> <li>- Global interest in sustainable tourism</li> <li>- Use of social media for wider marketing</li> <li>- International funding for conservation and sustainable tourism development</li> </ul>                                                                                                | <ul style="list-style-type: none"> <li>- Increasing demand for environmentally friendly agroforestry products (fruit, wood, medicinal plants)</li> <li>- Technological improvements in agroforestry that can improve yields and sustainability</li> <li>- Funding for conservation and sustainability projects from international organizations</li> </ul> |
| <b>Threats</b>       | <ul style="list-style-type: none"> <li>- Environmental damage if not managed carefully (water pollution, habitat damage)</li> <li>- Competition with other tourist destinations that are more advanced in terms of infrastructure and promotion</li> <li>- Climate change that can affect lake quality and biodiversity</li> </ul> | <ul style="list-style-type: none"> <li>- Risk of environmental damage due to unsustainable agroforestry practices (deforestation, soil pollution)</li> <li>- Natural disasters and climate change that can affect agricultural yields</li> <li>- Dependence on external investment and government policies that can change</li> </ul>                      |

## CONCLUSION

The Duma Galela Lake area has great potential for the sustainable development of water tourism and fisheries, although most visitors are local and domestic, there is an opportunity for more foreign tourists. The aquatic ecosystem is still able to support fishing activities carried out with the principle of sustainability. In addition to providing economic benefits to local communities, tourism revenue plays an important role in maintaining the sustainability of the industry. To maximize the potential of this area without damaging the existing ecosystem, in the future a more integrated and sustainable management will be needed. Agroforestry in the Duma Galela volcanic lake has great potential to improve the local economy and environmental conservation, according to the data presented. The large area of agroforestry, with different types of crops and different production outputs, suggests that this system can produce two advantages: increased income and nature conservation. The biodiversity recorded in this area shows that agroforestry helps preserve the environment and biodiversity and benefits the economy. This agroforestry system can serve as a model for other regions that want to build sustainable agricultural systems that support conservation by integrating forestry.

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