Status and condition of mangroves in sustainable management around the waters of Kulu village, Wori sub-district, North Sulawesi

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Abstract- Mangrove ecosystems along the coast of Kulu village in the Wori sub-district of East Likupang, Minahasa Regency, serve ecological, economic, and social functions that necessitate appropriate management for ensuring their sustainability. This study aims to achieve two objectives: (1) Analyzing the supportive factors in the management of mangrove ecosystems in North Minahasa Regency, and (2) Describing the sustainability status of various aspects in the management of mangrove ecosystems in the same region. The research was conducted between April and June 2023, specifically situated in Kulu village, Wori sub-district, East Likupang, North Minahasa. This paper presents a comprehensive examination of the health and sustainability of mangroves in the waters surrounding Kulu village, Wori sub-district, Minahasa Regency, North Sulawesi. The study likely encompasses an assessment of the current ecological status, including factors such as mangrove species diversity, habitat conditions, and overall ecosystem health. The focus on 'sustainable management' implies an exploration of human impact, conservation practices, and community involvement aimed at ensuring the long-term viability of these mangrove ecosystems. The research may illuminate the specific challenges faced by these mangroves, potential successes in conservation efforts, and strategies for effectively managing the delicate balance between human needs and environmental preservation in this particular region.

Index Terms- Mangrove, sustainable; Kulu Village, diversity

1. INTRODUCTION

Mangrove ecosystems, renowned for their ecological significance, play a pivotal role in coastal regions by providing habitat for diverse flora and fauna, preventing shoreline erosion, and sustaining local communities (Lee *et al.*, 2014; Mukherjee *et al.*, 2014). This study, set against the backdrop of Kulu village in the Wori sub-district of Minahasa Regency, North Sulawesi, seeks to explore the delicate balance between natural processes and human activities. Its goal is a comprehensive understanding of the 'Status and Condition of Mangroves in Sustainable Management.

Over 96% of the region is documented as ocean, covering an extensive area of 242,825 km2, establishing it as a prominent maritime and tourism hub (Oktaviana *et al.*, 2021). North Sulawesi waters boasts diverse natural beauty potential, strategically positioned for national and even international marketing efforts. As a maritime expanse, furthermore, North Sulawesi waters encompasses nature along all coastal regions and seas (Paendong *et al.*, 2023). The mangrove forest, a valuable asset along the shores, was reported to cover 3.48 million hectares in Indonesia by the Ministry of the Environment in 2017. This accounts for 19% of the global mangrove forest area, indicating significant growth potential for Indonesia. However, there exists a disparity between the perceived value of mangrove forests and their actual resilience in Indonesia. The quality and quantity of these forests are declining, affecting their role as a sediment storage region. Despite being a highly productive ecosystem with crucial social, economic, and environmental functions, the mangrove forests in Indonesia face challenges in sustaining their effectiveness (Kusmana, 2014; Lee, 2019; Kurnianingsih *et al*., 2021).

Nestled within the captivating landscapes of North Sulawesi, Kulu village hosts a unique mangrove ecosystem, acting as a critical link between terrestrial and marine environments. Acknowledging the pivotal role of mangroves in maintaining biodiversity, regulating coastal ecosystems, and supporting local livelihoods, this study aims to assess the current state of these ecosystems and explore avenues for sustainable management.

Situated in Wori sub-district, the waters surrounding Kulu village present a distinctive ecological context shaped by local geography, climate, and socio-economic factors. Understanding the intricacies of this location is crucial for comprehending the challenges and opportunities associated with mangrove conservation and sustainable management.

The primary objective of this research is to provide a detailed analysis of the status and condition of mangroves in the specified area. By examining factors such as species diversity, ecosystem health, and human interactions, the study aims to offer valuable insights that can inform sustainable management practices, ensuring the longevity of these crucial coastal ecosystems.

Emphasizing the concept of sustainable management underscores the need to balance conservation goals with the socio-economic realities of the local community. Achieving a harmonious coexistence between human activities and mangrove ecosystems requires an understanding of the delicate equilibrium that sustains these habitats and the potential repercussions of unsustainable practices.

Incorporating a community-centric approach, the study acknowledges the integral role of local residents in the sustainable management of mangroves. Simultaneously, it recognizes the challenges posed by anthropogenic activities, climate change, and other external factors, necessitating adaptive conservation strategies.

Coastal areas serve as meeting points between marine and terrestrial ecosystems, offering habitats for various organisms and providing resources and environmental services essential for human well-being. However, the concentration of human activities in these regions can exert immense pressures, leading to social, economic, and ecological issues. The impact of these pressures might jeopardize the existence and sustainability of mangrove communities.

The urgency of this research lies in empowering the economic value of coastal communities by determining the status and bioecological conditions of mangrove ecosystems within or around conservation areas. Managing these ecosystems necessitates a balance between their economic and ecological value. Seven environmental parameters—Temperature, protected area, current, substrate type, shallow exposure, salinity, and tidal range—have been identified as key determinants of mangrove distribution (Sasauw *et al*., 2016; Arfan, 2018; Irsadi *et al.*, 2019).

The anticipated outcomes of this research include actionable insights into effective conservation strategies and sustainable management practices tailored to the specific needs of the Kulu village mangrove ecosystems. By contributing to a broader understanding of mangrove dynamics, this study aims to lay a foundation for informed decision-making and policy formulation, promoting a balanced coexistence between human communities and these precious coastal ecosystems.

2. METHOD

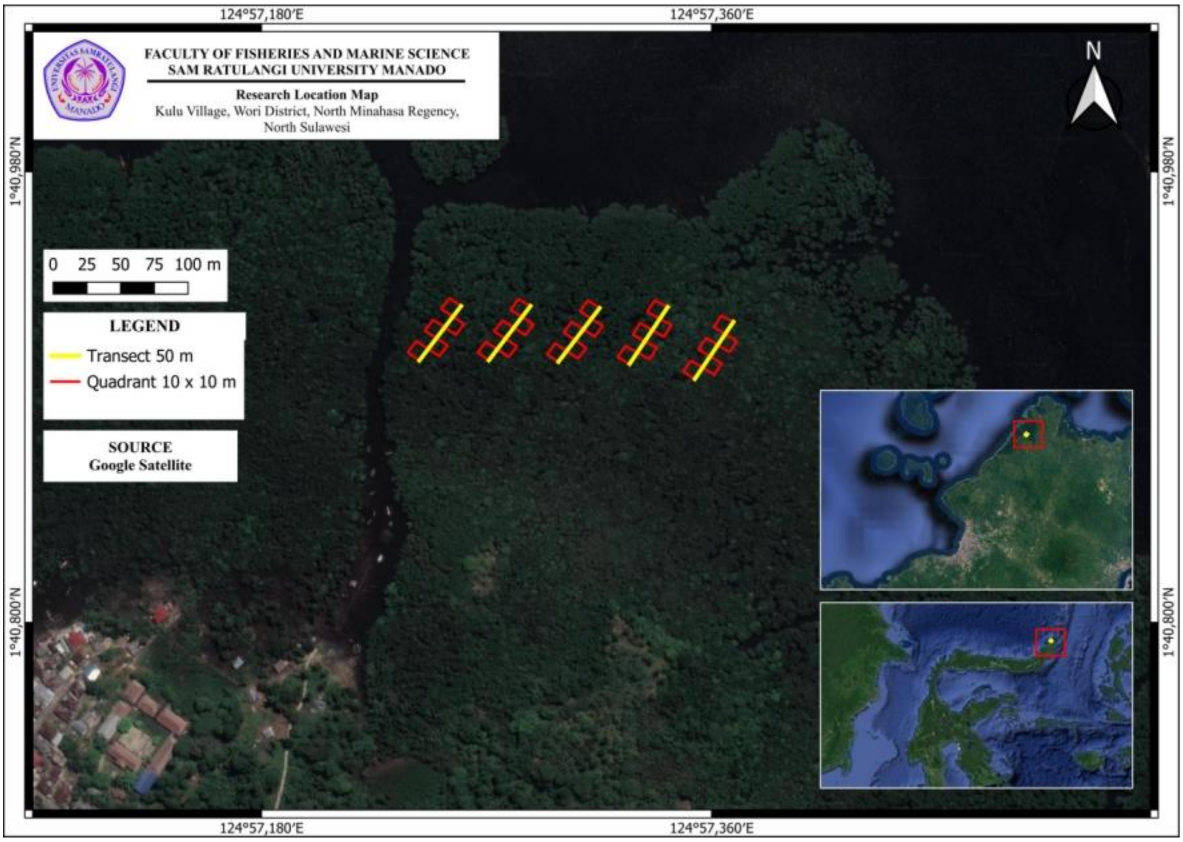

Figure 1. Location of the study site within the Kulu mangrove area at Kulu Village

Data collection. The primary equipment used for data collection was a 50 m x 10 m line transect covering a 500 m² observation area. Transects were laid perpendicular to the coastline, starting from the mangrove land boundary. Data for all types of mangroves within quadrants along the 50 x 10 m transect line were recorded. Three line transects were placed for data collection at each of the five (5) research sites. In addition to in-situ measurements of tidal fluctuations, salinity, and water temperature, photographic documentation was also carried out to complete the environmental information.

Description of the study sites. This research was conducted in Kulu Village along the coast of North Sulawesi, Indonesia (Figure 1), approximately 20 km away from the provincial capital of Manado. The coastline of this village falls within the supporting zone of Indonesia's Bunaken National Park. The village is significantly affected by the monsoon season, experiencing heavy rainfall from January to October 2023, while the remaining months are relatively dry. The environmental pressures in this area stem from the strong monsoon winds during the rainy season and the historical high rate of exploitation of mangrove woods, dating back around five decades. As a result, the community has taken measures to protect the mangrove area from further exploitation.

Avicennia marina	*Rhizopora apicula*	*Bruguira gymnorrhiza*

Rhizopora mukronata	*Rhizopora mukronata*	*Soneratia alba*

Using data from the file 'MangrovePunya.xlsx,' various types of analysis can be conducted:

1. Descriptive Analysis: This involves basic statistics like mean, median, mode, range, and standard deviation for each mangrove species at every station, providing an overview of their distribution and density across stations.
2. Correlation Analysis: This determines relationships between different mangrove species, offering insights into their interdependencies and correlations.
3. Analysis of Variance (ANOVA): This helps identify significant differences in the number of individuals of different mangrove species among various stations.
4. Cluster Analysis: By grouping stations based on similarities in mangrove species composition, this analysis can identify areas sharing similar mangrove ecosystem characteristics.
5. Temporal Trend Analysis (if data has a time component): This examines changes in the number or distribution of mangrove species over time.
6. Regression Model: It helps understand factors affecting mangrove distribution and density, like environmental conditions or anthropogenic factors, if relevant data is available.

Spatial Analysis: If geospatial data is accessible, this analysis can identify spatial distribution patterns of mangroves across stations.

Interpretation of Mangrove Data Analysis:

Descriptive Analysis Findings:

- *Rhizophora mucronata*: Average density approximately 9.8 per station with a standard deviation of 5.36, indicating significant variation between stations.
- *Rhizophora apiculata*: Exhibits the highest mean density among all species at 18.8, with a deviation of 7.26.
- *Rhizophora stylosa*: Shows an average density of 12 with a deviation of 7.87, implying significant differences between stations.
- *Bruguiera gymnoriza*: Lower average density (4.6) with less variation (3.21) compared to *Rhizophora* sp.
- *Soneratia alba* and *Avicennia marina*: Both exhibit lower average densities (3.8 and 1, respectively) and less variation.

Correlation Analysis:

- *Rhizophora mucronata* and *Rhizophora apiculata*: Display a strong negative correlation (-0.77), suggesting an inverse relationship between their densities at stations.
- *Rhizophora stylosa*: Shows significant positive correlations with *Soneratia alba* (0.72) and *Avicennia marina* (0.81), indicating concurrent high densities.
- *Bruguiera gymnoriza* and *Rhizophora apiculata*: Also show a strong positive correlation (0.73), hinting at similar habitat preferences or ecological interactions.

Interpretation:

- Density Variation: Significant density variations across stations possibly arise from differing environmental conditions like water quality, soil type, and exposure to external factors.
- Ecological Relationships: Correlations between species may signify ecological relationships like competition, coexistence, or similar habitat preferences.
- Conservation Importance: The data is crucial for conservation, highlighting dominant species in an area and relationships between different species.

This analysis utilizes available data and doesn't consider external or temporal factors that could influence mangrove distribution and density. Further studies, including spatial and temporal analyses (where data is available), will offer a deeper understanding of mangrove ecosystem dynamics.

The accompanying graph illustrates two aspects of mangrove data analysis:

1. Bar Graphs for Descriptive Statistics (Figure 02): Depict the mean and standard deviation for each mangrove species per station, visually representing average density and variation between species. *Rhizophora apiculata* shows the highest average density, while *Avicennia marina* displays the lowest.
2. Correlation Matrix (Figure 03): A heat map displaying the correlation matrix between species. Strong positive or negative values near 1 or -1 indicate significant correlations. For instance, the strong negative relationship between *Rhizophora mucronata* and *Rhizophora apiculata* (-0.77) is evident. Similarly, a strong positive relationship between *Rhizophora stylosa* and *Soneratia alba*/*Avicennia marina* is apparent.

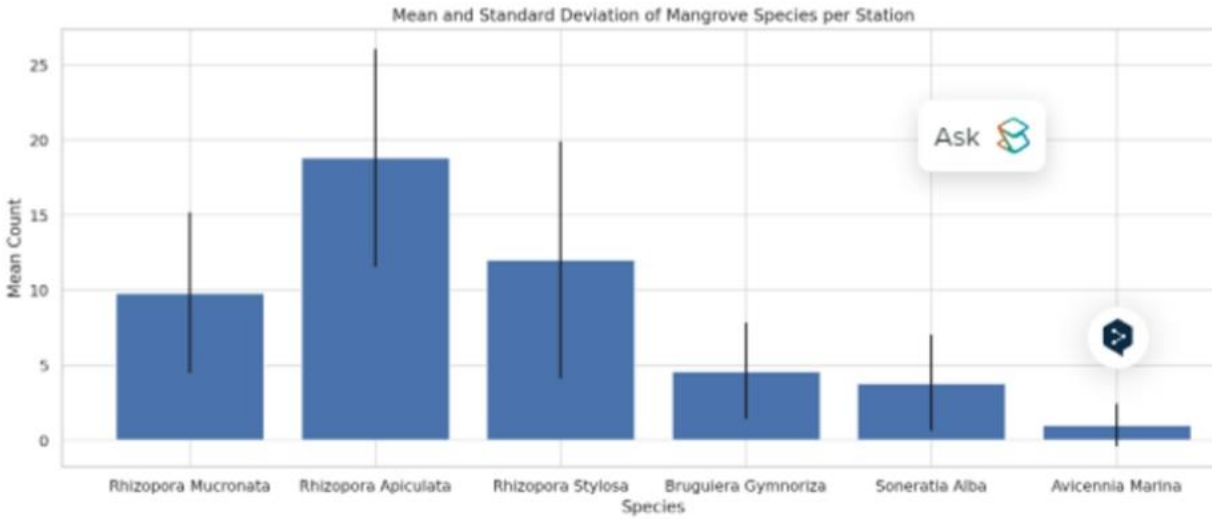

Figure 02. Mean and standard deviation of each mangrove species per station

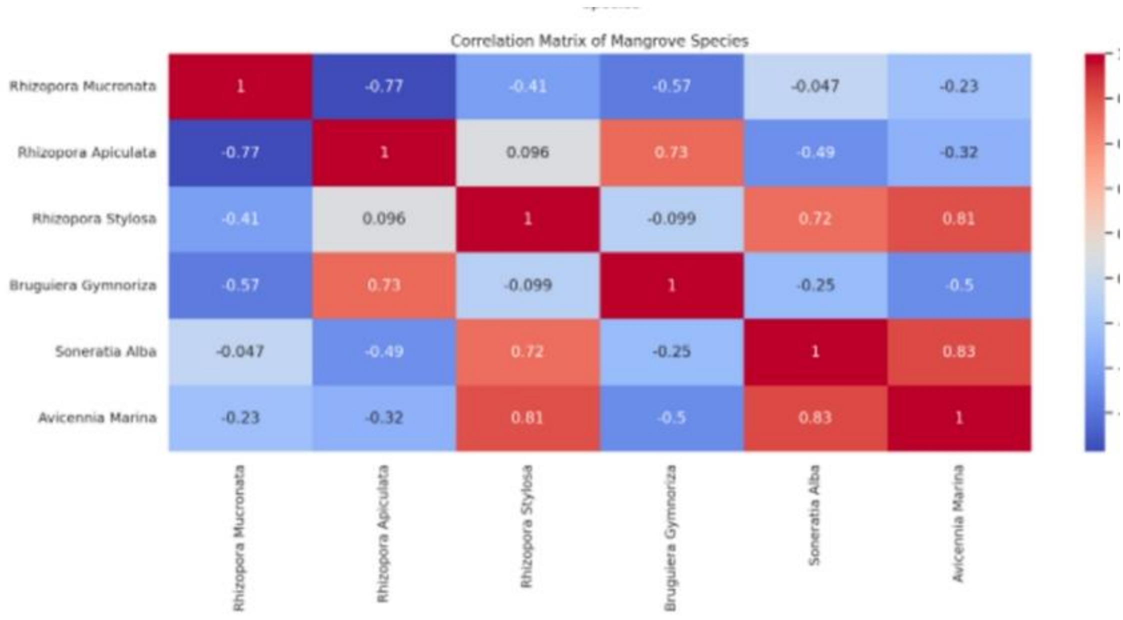

Figure 03. Correlation matrix between species

Interpretation; based on Malik *et al.* (2015) equations ;

- **Shannon Index (H')**

$$H' = -\sum(p_i \cdot \ln p_i)$$

A high value at station 1 indicates a greater variety of species, while stations 2 and 3 exhibited the lowest diversity among all stations.

- **Simpson Index (D)**:

$$D = 1 - \sum(p_i^2)$$

Values nearing 1 indicate both high diversity and an even distribution of species. Stations 1 and 4 demonstrate this condition, while station 2 suggests the potential dominance of certain species.

Margalef Index (DMg):

$$DMg = \frac{S-1}{\ln N}$$

The higher values observed at station 3 indicate a more significant variation in species. Conversely, similar values across the other stations suggest a relatively consistent level of diversity among them.

These findings offer a comprehensive view of mangrove species diversity and distribution at each station, significantly benefiting ecological studies and conservation initiatives. Additionally, I will present the formulas for each ecological index employed, accompanied by detailed interpretations. These elaborations aim to enhance comprehension of the results, particularly for journal review purposes.

Interpretation of Results:

• Station 1: Exhibits high diversity as indicated by the Shannon Index (1.60) and Simpson Index (0.78). This suggests a more balanced distribution of species with less dominance by particular species. The relatively elevated Margalef Index (1.23) signifies a good variety of species relative to the population size.

• Stations 2 and 3: Display lower Shannon and Simpson values, indicating reduced diversity and possible dominance by one or a few species. Notably, station 3 shows a higher Margalef Index (1.44) than station 2, suggesting greater species richness.

• Stations 4 and 5: Demonstrate higher diversity based on the Simpson Index (0.75 and 0.76), reflecting a more uniform distribution of species. The higher Shannon Index corroborates this observation. Similar Margalef Index values between these stations indicate a consistent level of species richness.

3. DISCUSSION

The focus of the ecological index analysis was to evaluate mangrove species diversity across distinct stations. Station 1 emerged as a standout, showcasing the highest diversity and uniformity among all stations. This indicates a rich variety of mangrove species with a balanced distribution.

In contrast, Station 2 displayed lower diversity, suggesting a narrower range of mangrove species present. This discrepancy might be influenced by distinct environmental factors unique to each station, such as soil composition, tidal patterns, or human impact.

Station 3 presented lower overall diversity but exhibited a notable richness in individual species. This suggests a higher abundance of specific species, contributing to a different facet of ecological richness.

Stations 4 and 5 demonstrated similar levels of diversity and uniformity, signifying a stable ecological balance. Such consistency often denotes a resilient ecosystem, offering valuable insights into mangrove community dynamics.

Understanding these diversity variations among stations is crucial for tailored ecological studies and conservation strategies (Srivastava & Reddy, 2023). The status of the mangrove ecosystem in Kulu village, Minahasa Northern Regency, Indonesia, significantly impacts sustainable management in this coastal region.

A comprehensive assessment reveals that these ecosystems face challenges and opportunities in pursuit of sustainability. The mangroves in Kulu village hold immense ecological importance, providing critical habitats, supporting local fisheries, and acting as natural barriers against coastal erosion and extreme weather (Malik *et al*., 2019)

However, their rapid degradation due to deforestation, pollution, and urbanization threatens their long-term health. Prioritizing conservation and restoration efforts through community engagement, effective policies, and sustainable livelihoods is essential. Scientific research and monitoring play key roles in tracking ecosystem changes and guiding adaptive management strategies.

4. CONCLUSIONS

In conclusion, the status and condition of the mangrove ecosystem in Kulu village, Minahasa Northern Regency, Indonesia, play a pivotal role in supporting sustainability management within the coastal region. A comprehensive assessment reveals that these ecosystems face both challenges and opportunities in their pursuit of sustainable management.

The ecological significance of the mangrove ecosystems in Kulu village is invaluable. They provide vital habitats for diverse species, bolster the local fisheries industry, and serve as natural buffers against coastal erosion and extreme weather events. However, rapid degradation due to deforestation, pollution, and urbanization poses a severe threat to their long-term health and resilience.

Efforts directed at sustainability management should prioritize the conservation and restoration of these fragile ecosystems. This necessitates community engagement, effective policies, and the promotion of sustainable livelihoods that do not compromise these valuable habitats. Furthermore, ongoing scientific research and monitoring are essential to track changes and guide adaptive management strategies.

The status and condition of the mangrove ecosystem in Kulu village underscore the necessity for a holistic and proactive approach to sustainable management. Safeguarding these ecosystems not only protects biodiversity and essential ecosystem services but also contributes to the well-being and resilience of local communities and the broader coastal environment.

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References

[1] Lee, S. Y., Primavera, J. H., Dahdouh-Guebas, F., McKee, K. L., Bosire, J. O., Cannici, S., Diele, K., Fromard, F., Koedam, N., Marchand. C., Mendelssohn, I. A., Mukherjee, & Record, S. (2014). Ecological role and services of tropical mangrove ecosystems: A reassessment. *Global Ecology and Biogeography*, *23*(7). doi:10.1111/geb.12155

[2] Mukherjee, N., Sutherland, W. J., Dicks, L., Huge, J., Koedam, N., & Dahdouh-Guebas, F. (2014). Ecosystem Service Valuations of Mangrove Ecosystems to Inform Decision Making and Future Valuation Exercises. *PLOS ONE*, *9*(9). e107706.

[3] Oktaviana, R. F., Muhammad, A. S., Kurnianingsih, F., & Mahadiansar, M. (2021). Internal condition analysis on tourism development of Bintan Regency 2019. *Indonesian Journal of Tourism and Leisure*, *2*(1), 51–61. https://doi.org/10.36256/ijtl.v2i1.129

[4] Paendong, M., Rambing, P., Simanjuntak, C., Kumaat, A., Marentek, M. & Mandey, N. (2023). Digital Marketing Ecosystem Perspective of Regional Featured Product in North Sulawesi Province, Indonesia. *Open Journal of Social Sciences*, *11*, 1-17. doi: 10.4236/jss.2023.112001.

[5] Kusmana, C. (2014). Distribution and Current Status of Mangrove Forests in Indonesia. *In book: Mangrove Ecosystems of Asia*, 37-60. doi:10.1007/978-1-4614-8582-7_3

[6] Lee, J-h. (2019). Conflict mapping toward ecotourism facility foundation using spatial Q methodology. *Tourism Management*, *72*, 69-77.

[7] Kurnianingsih, F., Zulkarnain, I., & Mahadiansar, M. (2021). How Socio-Economic Impact Tourism Development in Pandemic COVID-19? Study of Bintan Regency, Indonesia. *International Journal of Social Science and Religion* (IJSSR), *2*(2), 175–190. https://doi.org/10.53639/IJSSR.V2I2.46

[8] Sasauw, J., Kusen, J. D., Scadouw, J. N. (2016). "Community Structure of Mangrove in Tongkeina Village, Manado City." *Jurnal Pesisir dan Laut Tropis*, *2*(1), pp. 17-22, doi:10.35800/jplt.4.2.2016.13929.

[9] Arfan, A. (2018). Factors That Influence The Change Of Mangrove Forest In South Sulawesi, Indonesia. *UNM Geographic Journal 1*(2). doi: https://doi.org/10.26858/ugj.v1i2.5409

[10] Irsadi, A., Anggoro, S., & Soeprobowati, T. R. (2019). Environmental Factors Supporting Mangrove Ecosystem in Semarang-Demak Coastal Area. *E3S Web of Conferences*, 125, 01021. https://doi.org/10.1051/e3sconf/2019125010

[11] Malik, A., Fensholt, R., & Mertz, O. (2015). Mangrove exploitation effects on biodiversity and ecosystem services. *Biodiversity and Conservation*, *24*, 3543-3557.

[12] Srivastava, B. & Reddy, P. B. (2023). Recent Advances in Biodiversity Research. Publisher: International Multidisciplinary Research Foundation Ratna Prasad Multidisciplinary Research & Educational Society # 1-90, Near VTPS Main Gate, Ibrahimpatnam, Vijayawada, A.P., India. ISBN: ISBN 978-93-90146-61-1.

[13] Malik, A., Rahim, A., Sideng, U., Rasyid, A., & Jumaddin, J. (2019). Biodiversity assessment of mangrove vegetation for the sustainability of ecotourism in West Sulawesi, Indonesia. *AACL Bioflux*, *12*(4), 1458-1466.