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INTEGRATION OF SUSTAINABLE FOREST MANAGEMENT WITH ECOSYSTEM SERVICES PERFORMANCE IN CLIMATE CHANGE RESILIENCE IN NORTH MOROWALI

Abdul Rahman[1)], Arman Maiwa[1)], Hamka[1)], M. Kurniawan[2)], Sofyan[3)]

[1)]Faculty of Forestry, Tadulako University.
[2)]Faculty of Mathematics and Natural Sciences, Tadulako University.
[3)]Postgraduate of Agricultural Sciences, Tadulako University.

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ABSTRACT

Climate change is a major challenge that affects ecosystem resilience and human life, including in Indonesia, especially in North Morowali Regency which has extensive tropical forests. This study aims to assess the contribution of ecosystem services in climate regulation in the region and analyze how climate change interacts with ecosystem performance. The methodology used involves assessing ecosystem services for climate regulation and changes in forest land cover. The study's results indicated that forest dominance significantly aided climate regulation, with conservation forest areas contributing 21.51%, protected forests 20.68%, and production forests 19.52%, particularly in carbon sequestration and climate change mitigation. In contrast, non-forest areas showed a lower contribution. Regional resilience to climate change, it is recommended that the management of conservation and protected forests be strengthened, by considering the potential of ecosystem services they have in mitigating and adapting to climate change.

Keywords: Forest Management, Ecosystem Services, and Climate Change.

INTRODUCTION

Climate change is a global challenge that increasingly threatens the resilience of ecosystems and human life, with more visible impacts on various sectors, including natural resources and forest management (Maxwell et al., 2022). Indonesia, as a country with high biodiversity, faces major challenges in maintaining the balance of forest ecosystems that are greatly influenced by climate change factors (Pradana et al., 2022; Sangadji et al., 2019). North Morowali Regency, characterised by vast tropical forests, is subject to numerous effects of climate change, including rising temperatures, alterations in precipitation patterns, and the risk of natural disasters such as floods and landslides that jeopardise the sustainability of human livelihoods and ecosystems.

Sustainable forest management is one of the important approaches in maintaining ecosystem balance (Fraser, 2023), especially in increasing resilience to climate change (Huang et al., 2023). One of the main aspects that must be considered in forest management is the performance of ecosystem services (Sangadji et al., 2019, 2023), including the function of forests in absorbing carbon and having a direct contribution to climate change mitigation and adaptation (Lee et al., 2020; Wilson et al., 2023).

Healthy and sustainable ecosystem services can increase local resilience to the impacts of climate change while strengthening the capacity of communities to adapt to environmental changes that occur (Lavorel et al., 2020). Climate change in North Morowali Regency requires a profound understanding of the important role of forests as ecosystem services with dual regulatory functions, both for mitigation and adaptation to the impacts of climate change (Muis et al., 2024; O'connell, 2022).

The existence of forests in North Morowali Regency has enormous potential to play an important role in mitigating climate change, especially through its ability to absorb carbon (Simpson et al., 2021). Forests, as a fundamental element of the global ecosystem, serve as efficient carbon sinks that mitigate atmospheric greenhouse gas emissions. (Huang et al., 2023; Simpson et al., 2021). Carbon stored in forest biomass, both in stems, roots, and leaves, functions as an important carbon reservoir in the global carbon cycle (Nonini & Fiala, 2021).

The importance of forest management based on the performance of ecosystem services that regulate the climate sustainably (Jhong et al., 2019; Umar & Kadeko, 2015) can provide benefits: first, improving environmental conditions that support the social and economic sustainability of the community (Muis et al., 2024; Yulianti et al., 2024), and second, strengthening the resilience of the ecosystem itself to the impacts of climate change that continue to grow (Zhang et al., 2022).

The importance of ecosystem services in sustainable forest management is clear, but integrating forest management with climate regulation services needs to be carried out to enhance climate change resilience in North Morowali Regency (Mina et al., 2022; Nahib & Suwarno, 2018). Therefore, this study is expected to provide a significant contribution to efforts to adapt and mitigate climate change through sustainable forest management that relies on ecosystem services for climate regulation.

This study intends to investigate how the integration of sustainable forest management with ecosystem service performance can increase resilience to climate change in North Morowali Regency. This research also seeks to identify the performance conditions of ecosystem services that regulate the climate in improving forest management to support resilience to climate change.

RESEARCH METHODS

Evaluating the dynamics of multi-risk processes and climate change necessitates the disaggregation of the magnitude and frequency of various hazardous events over place and time, as well as an examination of how climate change influences the efficacy of local climate control ecosystem services. (Sangadji et al., 2023; Simpson et al., 2021). Materials and instruments used in processing spatial data on ecosystem services for climate regulation in North Morowali Regency are:

1) Ecoregion Maps at a scale of 1:250,000, issued by the Ministry of Forestry of Indonesian, in 2021, which has been verified by the Badan Informasi Geospasial (BIG) Indonesia

2) A land cover map at a scale of 1:250,000 was used in the preparation of the Regional Spatial Plan (RTRW) of North Morowali Regency, verified by the Geospatial Information Agency.
3) Administrative Map of the study area at a scale of 1:500,000 sourced from the Badan Informasi Geospasial (BIG) or the Regulation of the Minister of Home Affairs.
4) The results of expert assessments, which were compiled through questionnaires or lists of questions completed by experts, pertain to the contribution and role of ecoregions and land cover in ecosystem services, utilising the scoring method (Nazer et al., 2023).
5) A computer with Quantum GIS Software (QGis) to process and analyse spatial data on climate change based on ecosystem services (Muis et al., 2024; Sangadji et al., 2023; Nahib & Suwarno, 2018).
6) Other sectoral secondary data, both tabular and spatial, that are relevant to the research.

The assessment of ecosystem services is derived from evaluating and contrasting the contributions of ecoregions and land cover to these services (Nazer et al., 2023; Sangadji et al., 2023). An increased value of ecosystem services correlates with an elevated environmental carrying capacity (Sutrisno et al., 2023). The evaluation of the role of each landform, plant type, and land cover type is conducted through an expert-based assessment technique, specifically utilising focus group discussions among many experts. The index class (Table 1) describes the ecosystem services formula, which provides an indicative class of environmental conditions.

$$\boldsymbol{I_{ec}} = (W_{ls} x S_{ls}) + (W_{veg} x S_{veg}) + (W_{lc} x S_{lc})$$

As: **lec** is the ecosystem service index, W_{ls} is the landscape weight, S_{ls} is the landscape score, W_{veg} is the vegetation weight, S_{veg} is the vegetation score, W_{lc} is the land cover weight, and S_{lc} is the land cover score.

Table 1. Class of ecosystem services climate regulation and disaster regulation

Class of Carrying Capacity	Ecosystem services index
Very low	1.00- 1.80
Low	1.81 -2.60
Moderate	2.61 -3.40
High	3.41 -4.20
Very high	4.21 -5.00

RESULTS AND DISCUSSION

Area forests in the Regency North Morowali, as much as 71.51% of the total area of the regency, consist of forest conservation (25.09%), forest protected (22.45%), forest production (23.96%) and not forest (28.49%). The forest area plays an important role in climate management by providing ecosystem services (Longo et al., 2024). Knowledge integration of service ecosystems in planning areas can increase the effectiveness of adaptation strategies to change the climate. The incorporation of ecosystem results into spatial planning, sustainable forest management, and decision-making enhances the capacity and resilience to adapt to climate change (Longo et al., 2024; Rayden et al., 2023).

Studies show every functional area of a forest has its ability or contribution to arrange climate (Queiroz et al., 2024). Results of the study service ecosystem arrangement climate, area forest conservation, and own distribution are big in the "high" (17.30%) and "very high" (4.21%) categories, although it only covers a small percentage in other categories. The result is reflected in area conservation has its own significant function in climate arrangements (Gul Zareen et al., 2023). Forest area protection shows a similar pattern, with the most contribution in the high (10.21%) and very high (10.47%) categories. Some aspects of forest area

protection are still effective in their role within climate arrangements. Research shows that forest management and conservation positively influence service settings, such as CO_2 regulation and climate service arrangements. For resilience adaptation, change the climate in the local area (Sasanifar et al., 2024).

In the short term, areas of forest production tend to contribute less to climate settings compared to areas focused on forest conservation and protection. Although so, this area still shows sufficient significant contribution in the categories "medium" (4.28%) and "high" (8.72%), as well as "very high" (10.81%). Lastly, non-forest areas show a greater proportion of being in the category of more contribution being low, such as “very low" (0.87%) and "low" (1.06%), with a little contribution to the "high" (8.35%) and "very high" (2.61%) categories. This shows that non-forest areas have a limited role in climate arrangements compared to forest areas. The importance of trees: This increases the local ecosystem and reduces climate impact.

Variation contributes to the area of forest in climate arrangements, with forest areas being the most important conservation and protection significant in guarding climate balance, while non-forest areas have relatively less influence (Gregor et al., 2024). Research emphasizes that forests play an important role in carbon storage and emission reduction capability for forest service ecosystem arrangements and climate (Zhong et al., 2024). Dominance forest contribution is tall in arrangement climate, and area forest conservation contributes 21.51% of forests protected, contributing 20.68% and forest production contributes 19.52%, especially in carbon storage and climate impact mitigation. On the other hand, non-forest areas show a lower contribution.

Urbanized areas face the challenge of changing the ecosystem services in response to climate, especially in developing areas (Maxwell et al., 2022; Zhong et al., 2024). Lack of management can increase vulnerability to dangerous situations, which points to the need for more compensation and support. Maintaining a service ecosystem on owner land is beneficial and crucial for managing the climate.

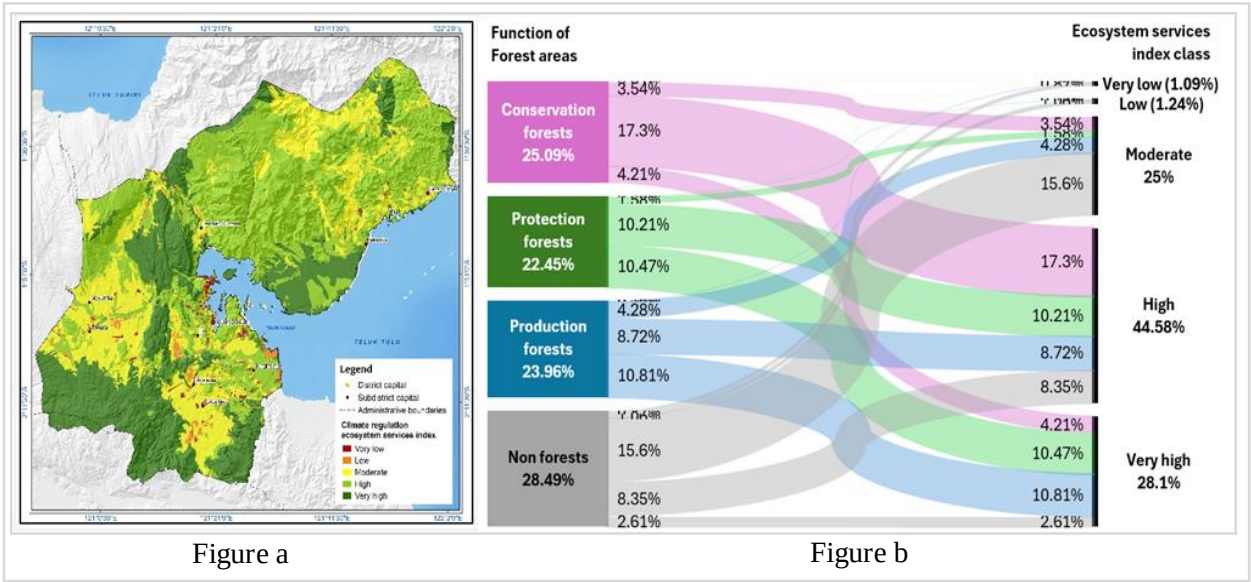

Figure a Figure b

Figure 1. Climate regulation ecosystem service index illustration. Figure (a) climate regulation ecosystem service map and figure (b) forest area function diagram contributing to ecosystem service index class.

The conversion of forests to non-forest land is a substantial alteration in land use with profound consequences for climate change. The experience of forest conservation in broad wooded areas diminished from 35.09% to 29.39%. Meanwhile, forest protection and forest production each experienced a decline in forested areas to 28.91% and 27.04%, respectively. The conversion of forest land into non-forest areas, such as agricultural land and bare land, dominates most of the changes. Phenomenon This describes how the transfer of land from potentially forested areas affects ecosystem sustainability and climate change.

Change this to involve the transformation of various types of land, including shrub that covers around 4.2% in conservation forests, 1.91% in forest protected areas, and 4.19% in forest production. In addition, conversion also includes land agriculture that exists in various categories of forest, although with a higher percentage of small, such as 0.05% in conservation forests and 0.07% in protection forests. Lands that are not productive or degraded, such as barren land, also recorded a change, although in a minimal proportion, namely 0.24% in conservation forests and 0.04% in production forests.

The conversion of forest to non-forest land is often driven by factors such as the need for agricultural land, development infrastructure, and utilization sources. Power is more nature intensive (Zhong et al., 2024). Changing use of rapid land, including conversion of forests, can threaten ecosystem sustainability and worsen climate change impact (Longo et al., 2024; Nazer et al., 2023). Therefore, it is important to consider policy management strategies that promote balanced forests and reduce the loss of ecosystems due to conversion. Regional resilience to climate change: it is recommended that forest conservation and protection management be reinforced (Fernández et al., 2022; Golar, et al., 2021), with notice of the potential service the ecosystem has in mitigation and adaptation to climate change.

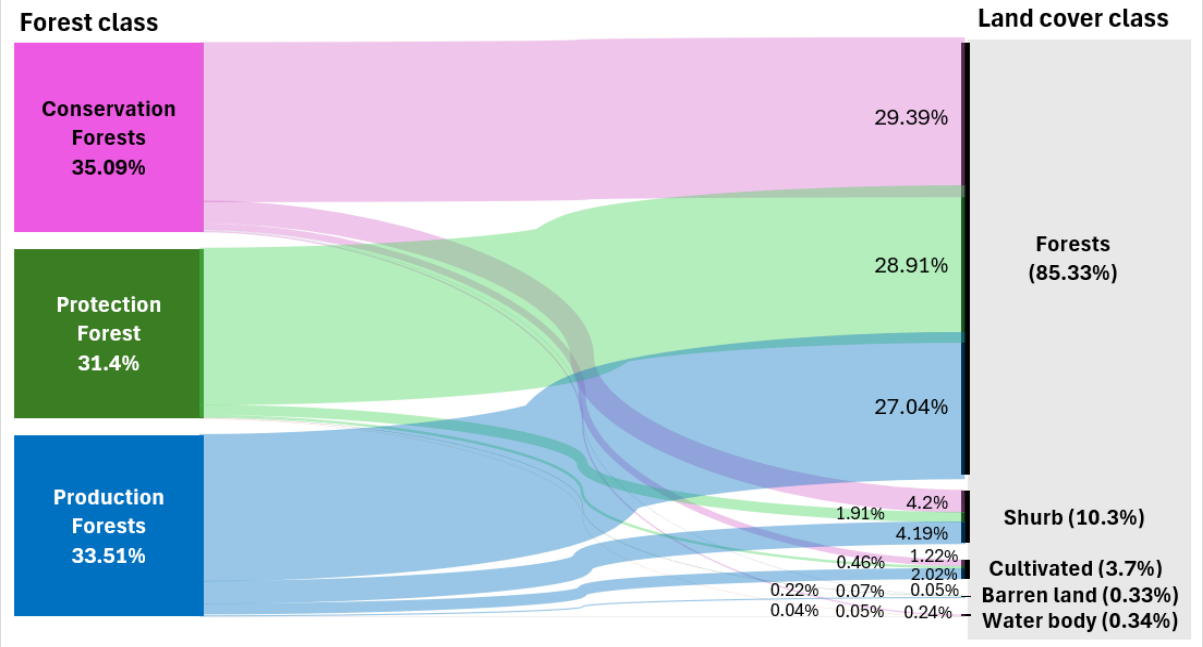

Figure 2. Overview of forest area functions and existing land cover

From 2003 to 2015, the area of mining in non-forest regions increased by 33.69%. The substantial expansion of mining company territories poses a threat

to the survival of forested regions in North Morowali Regency. Open pit mining operations result in the transformation of forested regions into non-forested areas. Furthermore, North Morowali Regency is home to approximately 30 plantation enterprises. Plantation activities pose dangers to alterations in land cover within forested regions.

Table 2. Strategies for developing forest management in climate change resilience

Forest Management Issues	Forest Management Strategies in Climate Change
Conversion of Forest to Non-Forest	Forest management should be balanced and planned to prevent the conversion of forest land to non-forest uses such as agriculture and infrastructure development. Strengthening the forest management on conservation forests and protected forests.
Decrease in Forest Area	Strengthening policies for managing conservation and protected forest areas, as well as restoring degraded forests to increase resilience to climate change.
The Role of Forests in Carbon Storage	Improving forest maintenance and restoration to increase carbon sequestration and reduce greenhouse gas emissions. Integration of ecosystem service performance systems for climate change mitigation.
Environmental degradation and loss of forest area	Formulation of policies that support the restoration of degraded forest ecosystems and prevent loss of function in forests. Conservation strategies are being developed to synchronies mining activities with forest protection. Integrating climate regulation ecosystem services into spatial planning.
Challenges in Urbanized Areas	Encourage compensation and support for landowners to maintain critical ecosystem services in rapidly developing areas. Integrate forest and urbanization policies for greater climate resilience.

From 2003 to 2015, the area of mining in non-forest regions increased by 33.69%. The substantial expansion of mining company territories poses a threat to the survival of forested regions in North Morowali Regency (Nahib & Suwarno, 2018; P. et al., 2024). Open pit mining operations result in the transformation of forested regions into non-forested areas. Furthermore, North Morowali Regency is home to approximately 30 plantation enterprises. Plantation activities pose dangers to alterations in land cover within forested regions.

Importantly, integrating system performance, ecosystem services, and forest land cover into an adaptation strategy for climate change (Pradana et al., 2022; Sasanifar et al., 2024) will inform policymakers and stakeholders about promoting a sustainable and resilient future (Golar, Muis, et al., 2021; Luu et al., 2024; Rahman et al., 2024).;’’’The maintenance and recovery of ecosystem services can play an important role in reducing global climate change by increasing carbon absorption and reducing greenhouse gas emissions, while improvements in land cover forests significantly enhance the resilience of ecosystems to climate change.

The North Morowali Regency Government needs to strengthen balanced forest management policies to prevent the conversion of forest land to non-forest land, such as for agriculture, infrastructure development and mining development. This can be done by strengthening the management of conservation forests and protected forests and restoring degraded forests to increase resilience to climate change (Longo et al., 2024).

In addition, it is important to improve forest maintenance and restoration to increase carbon sequestration and reduce greenhouse gas emissions and integrate climate-regulating ecosystem services into spatial planning (Sasanifar et al., 2024; Zhong et al., 2024). The government must

also formulate policies that support the restoration of damaged forest ecosystems (Muis et al., 2024), integrate forest protection with mining activities, and support landowners in urban areas to maintain important ecosystem services to increase the climate resilience of rapidly developing areas (Fraser, 2023; Gregor et al., 2024).

CONCLUSION

Changes in forest areas in North Morowali Regency, like the loss of conservation, protected, and production forests, could impact how well ecosystem services work, particularly in regulating the climate. Conservation and protected forest areas contribute significantly to climate regulation by storing carbon and mitigating climate change, while non-forest areas show a lower contribution. Changes in land cover, especially the conversion of forests to non-forest land such as agriculture and development, can reduce the effectiveness of climate regulation functions. Therefore, balanced and planned forest management, including strengthening conservation and protected forest policies and restoring degraded forests, is an important strategy to increase resilience to climate change. Forest management must also integrate systems for ecosystem service performance in spatial planning for more effective climate change mitigation.

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