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Analysis of the Impact of Land Use Change, Shrimp Farming Activities, and Climate Change on Biodiversity and Fishermen's Welfare in Lampung

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ABSTRACT

This study examines the impact of land use change, shrimp farming, and climate change on biodiversity and the welfare of fishermen in Lampung from a community perspective. Using a quantitative approach, data were collected from 70 respondents through a structured questionnaire and analyzed using SPSS version 26. The results reveal that land use change and shrimp farming have negative effects on biodiversity, while climate change significantly exacerbates these impacts. Biodiversity, in turn, strongly influences the welfare of fishermen, with reduced biodiversity linked to declining income stability and food security. Regression analysis indicates that environmental factors explain 58.3% of biodiversity variance, while biodiversity accounts for 33.6% of the variance in fishermen's welfare. The findings emphasize the importance of sustainable practices and integrated policies to mitigate environmental degradation and improve community livelihoods.

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1. INTRODUCTION

The interplay between environmental changes and socio-economic development in Lampung, Indonesia, is a complex issue influenced by land use change, shrimp farming, and climate change. These factors have significantly impacted the region's biodiversity and the livelihoods of local fishermen. The transition from traditional agroforests to monoculture plantations, driven by agricultural commercialization, reduces biodiversity and affects ecosystem services and local livelihoods, leading to socio-economic challenges, as seen in the Upper Citarum Watershed [1]. The loss of plant diversity can result in increased poverty among farmers [1]. Shrimp farming, a significant economic activity in Lampung, contributes to mangrove deforestation and water pollution, impacting fishery resources and biodiversity [2], making sustainable management practices essential to balance economic benefits with environmental preservation [2]. Climate change further exacerbates environmental degradation, threatening food security and economic stability [3], while the reliance on natural capital for economic growth presents mixed outcomes, potentially improving economic conditions but hindering poverty reduction and health outcomes [4]. This dynamic is further complicated by the Environmental Kuznets Curve (EKC), which suggests that economic growth initially leads to environmental degradation before improvements occur at higher income levels [5].

The expansion of shrimp farming in coastal areas like Lampung has brought significant environmental challenges, including habitat loss and ecosystem fragmentation. Although it provides substantial income and employment, shrimp farming poses serious risks such as mangrove deforestation, water pollution, and biodiversity loss, which undermine the livelihoods of fishermen dependent on healthy marine ecosystems. In places like Ca Mau Province, Vietnam, shrimp farming has led to extensive mangrove degradation [6], while farm waste causes persistent coastal water pollution [7]. The shift of fertile lands to aquaculture disrupts ecological balance and reduces biodiversity [8]. Economically, it supports many livelihoods [6], but environmental degradation threatens long-term productivity and profits [8]. Sustainable solutions, including mangrove restoration [7], targeted policies [6], and community involvement [9], are essential to balance economic benefits with ecological sustainability.

Climate change significantly impacts fishing communities in Lampung, Indonesia, through unpredictable weather patterns, rising sea levels, and shifts in marine species distribution, all of which disrupt fishing activities and heighten economic insecurity among fishermen who rely heavily on natural ecosystems. These challenges are intensified by the communities' dependence on traditional fishing methods and limited adaptive capacity. Unpredictable weather and extreme events reduce catch volumes and disrupt schedules [10], [11], while rising sea temperatures and shifting fish populations force fishermen to travel farther, increasing operational costs and safety risks [11] The continued decline in fish stocks further undermines the sustainability of fishing livelihoods [12], [13]. Traditional fishermen, whose household incomes primarily depend on fishing, face high vulnerability due to climate variability, with the income vulnerability index in Bandar Lampung City and South Lampung Regency indicating significant economic insecurity [10]. Financial strain also increases as fishermen require more advanced tools and longer trips to maintain income levels [11]. To cope, many adopt strategies such as livelihood diversification, adjusting fishing periods, and improving technology [11]. Strengthening community cooperation, expanding access to microfinance, and enhancing training and weather information access are essential to building resilience [11].

Understanding the interplay between these factors is essential for crafting sustainable strategies that balance ecological preservation with community well-being. This study investigates the impact of land use change, shrimp farming practices, and climate change on biodiversity and the welfare of fishermen in Lampung from the perspective of the affected community.

2. LITERATURE REVIEW

2.1 *Land Use Change and Its Environmental Impact*

Land use change, driven by deforestation, agricultural expansion, and urbanization, significantly contributes to global environmental degradation and biodiversity loss by disrupting ecosystems and causing habitat loss, particularly in tropical and coastal regions. In Lampung, the conversion of mangrove forests into shrimp farms exemplifies how such transformations reduce ecosystem services, directly impacting local communities dependent on these ecosystems for their livelihoods. Tropical forests, which are biodiversity hotspots, are heavily affected by activities like logging, mining, and agriculture, leading to habitat fragmentation [14]. Land use change also reduces α-diversity of bees by 16%–18% in agricultural and urban areas, impairing pollination and food production, although the effects on β- and γ-diversity vary depending on habitat type [15]. Moreover, global biodiversity loss is exacerbated by agri-food supply chains, particularly in biodiverse regions like Latin America and Southeast Asia, where increased exports drive ecological impacts [16]. The loss of natural habitats such as mangroves diminishes ecosystem services like coastal protection and water filtration, undermining local fisheries and livelihoods [17]. In southwest China, projections show that land use changes will decrease habitat quality and species richness despite currently high levels, highlighting future challenges for biodiversity conservation [18].

2.2 *Shrimp Farming: Economic Benefits and Environmental Costs*

Shrimp farming, particularly through intensive methods, has become a major economic activity in coastal regions due to high seafood demand, but this growth often incurs substantial environmental costs such as pollution and habitat degradation. Intensive shrimp farming contributes significantly to environmental impacts, including global warming potential and eutrophication, primarily from electricity and feed consumption [19], [20]. Wastewater and sediment from farms also degrade water quality and reduce surrounding fish populations [21]. However, super-intensive systems like biofloc technology offer more sustainable alternatives by minimizing water exchange and reducing impacts across multiple environmental categories [22]. Economically, shrimp farming supports local economies, though benefits are often unevenly distributed, favoring wealthier stakeholders while local fishermen suffer from reduced fish availability [23]. To balance economic and environmental concerns, adopting renewable energy and improving feed efficiency are recommended [19], [20]. Governments and local authorities are urged to implement waste treatment technologies and sustainable feed standards to mitigate environmental impacts [21], while researchers are encouraged to investigate microbial dynamics and life cycle assessment innovations to further enhance aquaculture sustainability [19].

2.3 *Climate Change and Coastal Communities*

Climate change significantly threatens biodiversity and the livelihoods of coastal communities by impacting marine ecosystems and altering fishing patterns. Rising sea levels, ocean acidification, and temperature fluctuations contribute to habitat degradation and shifts in species distribution, which reduce fisheries productivity and the availability of resources for small-scale fishermen, particularly in tropical regions where socio-economic vulnerabilities exacerbate these impacts. Coastal ecosystems such as mangroves, coral reefs, and seagrass meadows are experiencing habitat loss and biodiversity changes, leading to diminished ecosystem services like fishery yields and natural storm protection [24]. Ocean warming, deoxygenation, and acidification are altering fish distributions and body sizes, affecting nutrient availability and fisheries across Southeast Asia and Pacific Island nations [25]. These ecological shifts threaten food security and livelihoods in vulnerable regions reliant on wild-capture fisheries for essential micronutrients [25], while in the Western Caribbean, climate-induced changes in fishery resources have intensified both local and transboundary conflicts [26]. Adaptive responses such as ecosystem-based and co-management policies, alongside sustainable resource management, are crucial to mitigating these effects [24], [26]. Moreover, strengthening biodiversity and environmental protection through adaptive fisheries co-management can create more productive and food-secure conditions for farmers and fishers [27].

2.4 *Biodiversity and Ecosystem Services*

Biodiversity is essential for sustaining ecosystem services that support human well-being, including provisioning, regulating, and cultural functions, and its loss—driven by land use change, aquaculture, and climate change—has profound impacts, especially on communities reliant on natural resources. In coastal Lampung, declining fish stocks and habitat degradation threaten food security and income for local fishermen, reflecting the broader socio-economic consequences of biodiversity loss. Industrial development and land use changes have caused significant habitat degradation, a major driver of global biodiversity decline that undermines ecosystems' ability to meet human needs [28]. Biodiversity also supports agricultural productivity through services like pollination and pest control, and its reduction can lead to lower crop yields and greater vulnerability to pests, threatening food security [29]. Additionally, decreased biodiversity limits dietary diversity, increasing the risk of nutritional deficiencies and malnutrition, as biodiverse ecosystems are vital sources of varied, nutrient-rich foods [30]. Communities such as the fishermen in coastal Lampung are disproportionately affected, as declining natural resources directly impact their livelihoods and food access [28]. Furthermore, biodiversity contributes to human health by supporting clean air, water, and nutrition, and its loss can lead to negative health outcomes and diminished quality of life [31].

2.5 *The Welfare of Fishermen: Socio-Economic Perspectives*

The welfare of fishermen in Indonesia is closely tied to the health of marine ecosystems, with small-scale fisheries being especially vulnerable to environmental degradation and climate change. These communities often face low incomes, limited infrastructure, and restricted market access, challenges that are intensified by ecological pressures. In South Malang, small-scale fisheries exhibit high vulnerability to climate variability and natural disasters, particularly in sociodemographic and social network dimensions [32]. In response, fishermen in Pangkep Regency adopt adaptive strategies such as livelihood diversification, technological improvements, and strengthened community cooperation to cope with climate impacts [11]. Economic welfare in regions like the Talaud Islands is heavily influenced by fishing yields and access to financial resources, with those receiving capital from banks enjoying greater financial stability than those reliant on local fish buyers (Nelwan et al., 2024). In Pemalang Regency, smallholder fishermen generally experience moderate welfare levels, and enhancing access to capital and providing skills training are recommended to improve their socio-economic standing [33]. Moreover, sustainable fishing ports in East Java play a vital role in promoting responsible fishing and conservation, where market demand, community welfare, and infrastructure development are positively linked to the success of eco-fishing initiatives [34].

2.6 Theoretical Framework

This study is guided by the socio-ecological systems (SES) framework, which emphasizes the interconnectedness of human and natural systems (Ostrom, 2009). The SES framework provides a lens for analyzing how environmental changes, economic activities, and policy interventions influence community well-being and ecosystem health. By applying this framework, the research captures the complex interactions among land use change, shrimp farming, climate change, biodiversity, and fishermen's welfare in Lampung.

Despite extensive research on land use change, aquaculture, and climate change, there is limited empirical evidence on their combined impact from the perspective of affected communities in Lampung. Existing studies often focus on ecological or economic aspects in isolation, overlooking the socio-economic implications for fishermen. This study addresses these gaps by integrating community perspectives through a quantitative analysis, providing a comprehensive understanding of the challenges and opportunities in achieving sustainable development in Lampung.

3. METHODS

3.1 Research Design

The study utilized a descriptive and explanatory quantitative research design. This approach allowed for a detailed examination of the relationships among the variables: land use change, shrimp farming, climate change, biodiversity, and fishermen's welfare. The design facilitated the identification of causal relationships and the extent of their impact on the dependent variables.

3.2 Population and Sample

The target population for this study comprised fishermen and community members in Lampung who are directly or indirectly affected by environmental and socio-economic changes. A purposive sampling technique was used to ensure the inclusion of participants with relevant knowledge and experience. A total of 70 respondents were selected, representing a cross-section of the community to capture diverse perspectives. The sample size was deemed adequate for the scope of the study and suitable for statistical analysis.

3.3 Data Collection

Primary data were collected using a structured questionnaire designed to capture the perceptions and experiences of respondents, divided into five sections corresponding to specific variables: Land Use Change, which focused on the extent and perceived impact of land use transformations in the region; Shrimp Farming, assessing the economic and environmental effects of shrimp farming practices; Climate Change, exploring respondents' observations of climate-related changes and their influence on fishing activities; Biodiversity, measuring perceived shifts in marine biodiversity and its implications; and Fishermen’s Welfare, evaluating socio-economic conditions such as income stability, food security, and overall well-being. Responses were recorded on a five-point Likert scale ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree"), enabling nuanced analysis of participant opinions.

3.4 Data Analysis

The collected data were analyzed using SPSS version 26, employing both descriptive and inferential statistical techniques. Descriptive statistics were used to summarize the demographic characteristics of respondents and the mean scores of the study variables, while inferential methods such as correlation and regression analysis were applied to examine relationships among variables and test the research hypotheses. The data analysis process included several steps: data cleaning to ensure response accuracy and completeness; descriptive statistics to present demographic information and variable means; reliability testing using Cronbach’s alpha to assess the consistency of questionnaire items; correlation analysis to explore the strength and direction of relationships among variables; and regression analysis to determine the influence of independent variables—land use change, shrimp farming, and climate change—on the dependent variables, namely biodiversity and fishermen's welfare.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Descriptive statistics were computed to summarize the demographic characteristics of the respondents and their overall perceptions of green subsidies, tax incentives, and sustainable investment. In terms of demographics, 40% of respondents were

4.1.1 Demographic Profile of Respondents

The demographic data revealed that most respondents were male (78.6%), reflecting the predominant involvement of men in fishing activities. The majority of respondents were aged 30–50 years (65.7%), indicating that middle-aged individuals are the primary contributors to fishing activities in the region. Educational levels were low, with 64.3% having only primary or secondary education, which underscores the socio-economic challenges faced by the community.

4.1.2 Descriptive Statistics

The mean scores of the study variables revealed that Land Use Change had the highest mean (Mean = 4.21, SD = 0.68), followed by Climate Change (Mean = 4.02, SD = 0.71), Shrimp Farming (Mean = 3.87, SD = 0.74), Biodiversity (Mean = 3.65, SD = 0.81), and Fishermen's Welfare (Mean = 3.45, SD = 0.78). These results indicate that respondents perceived land use change and climate change as having significant impacts on biodiversity and fishermen’s welfare. Shrimp farming was also identified as a contributing factor, though perceptions were mixed, with respondents acknowledging both its economic benefits and associated environmental costs.

4.1.3 Correlation Analysis

Pearson correlation analysis revealed that land use change was negatively correlated with biodiversity ($r = -0.621$, $p < 0.01$), shrimp farming showed a moderate negative correlation with biodiversity ($r = -0.463$, $p < 0.05$), and climate change had a strong negative correlation with biodiversity ($r = -0.695$, $p < 0.01$). Additionally, biodiversity was positively correlated with fishermen's welfare ($r = 0.588$, $p < 0.01$). These findings suggest that land use change, shrimp farming, and climate change significantly reduce biodiversity, which in turn has a direct positive relationship with the welfare of fishermen, highlighting the interconnectedness of environmental and socio-economic factors.

4.1.4 Regression Analysis

Regression analysis was conducted to assess the extent to which land use change, shrimp farming, and climate change predicted changes in biodiversity and fishermen's welfare. The results showed that these three independent variables collectively explained 58.3% of the variance in biodiversity ($R^2 = 0.583$, $p < 0.01$), while biodiversity itself was a significant predictor of fishermen's welfare, accounting for 33.6% of its variance ($R^2 = 0.336$, $p < 0.01$). These findings confirm the hypothesis that environmental factors significantly influence biodiversity, which in turn has a substantial impact on the welfare of fishermen in Lampung.

4.2 Discussion

The findings align with studies highlighting the detrimental effects of land use change on coastal ecosystems. The high mean score for land use change reflects widespread community awareness of the negative consequences of deforestation and mangrove conversion for aquaculture. These practices reduce habitat availability for marine species, leading to biodiversity loss and declining fish stocks. This result corroborates [35], [36] findings on mangrove destruction in Southeast Asia.

Shrimp farming, while economically beneficial, has significant environmental drawbacks. Respondents acknowledged the income opportunities provided by shrimp farming but also expressed concerns about water pollution and habitat degradation. This dual impact echoes [19], [37] observations that intensive aquaculture often leads to long-term environmental costs, outweighing short-term economic gains.

The strong negative correlation between climate change and biodiversity supports existing research on the vulnerability of marine ecosystems to global warming. Participants reported erratic weather patterns, reduced fish catches, and increased fishing difficulties, which align with findings by [36], [38]. These changes pose substantial challenges for fishermen, particularly those lacking resources to adapt to shifting ecological and climatic conditions.

The positive correlation between biodiversity and fishermen's welfare underscores the critical role of healthy ecosystems in sustaining livelihoods. Communities with access to diverse marine resources reported higher levels of income stability and food security. This finding is consistent with [39], [40]assertion that ecosystem services are foundational to human well-being.

The results highlight the need for integrated policies that balance economic development with environmental conservation. Strategies such as mangrove restoration, sustainable shrimp farming practices, and climate adaptation measures are essential for protecting biodiversity and enhancing community resilience. These findings resonate with the socio-ecological systems framework [41], [42], which emphasizes the interdependence of human and natural systems.

5. CONCLUSION

This study highlights the significant interconnections among land use change, shrimp farming, climate change, biodiversity, and the welfare of fishermen in Lampung. The findings demonstrate that environmental factors, particularly land use change and climate change, have profound negative impacts on biodiversity. Shrimp farming, while economically beneficial, also contributes to environmental degradation. Biodiversity is a crucial determinant of fishermen's welfare, as its decline leads to reduced income stability and food security.

To address these challenges, integrated policies that balance economic development with environmental conservation are essential. Key strategies include promoting sustainable shrimp farming practices, restoring mangrove ecosystems, and implementing climate adaptation measures. Policymakers, stakeholders, and community leaders must collaborate to foster sustainable development and ensure the resilience of coastal communities.

This study provides a foundation for future research on environmental sustainability and community welfare, particularly in coastal regions facing similar socio-economic and ecological challenges.

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