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Local Economic Adaptation Strategies Towards the Impact of Global Warming in Eastern Indonesia

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Abstract
Global warming has had a significant impact on the local economy in Eastern Indonesia, a region encompassing East Nusa Tenggara, Maluku, North Maluku, Papua, and West Papua. This study aims to identify the specific impacts of global warming on key economic sectors and analyze adaptation strategies developed by local communities based on the framework of adaptive capacity theory. Using a qualitative literature study method with a systematic analysis of scientific publications, government reports, and policy documents over the past four years, this study found that global warming has had a serious impact on three sectors supporting the local economy: fisheries have experienced a 20-30 percent decline in catch due to coral bleaching and shifts in fish migration; agriculture has been disrupted by changing rainfall patterns, leading to uncertain planting seasons and increased pest infestations; and marine tourism has declined due to coastal ecosystem degradation. Communities have responded to these impacts through five main adaptation strategies: livelihood diversification, utilization of local knowledge and technological innovation, strengthening institutions and social networks, increasing access to finance and insurance, and developing value chains and market access. However, the effectiveness of these adaptation strategies remains constrained by a limited economic asset base, institutional weaknesses, knowledge gaps, limited innovation capacity, and weak coordination among stakeholders. This study concludes that increasing local economic resilience requires a holistic approach that simultaneously strengthens all five dimensions of adaptive capacity through infrastructure investment, institutional strengthening, human resource capacity building, and responsive policies, with active collaboration between the government, local communities, the private sector, and non-governmental organizations.

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1. INTRODUCTION

Indonesia, as a tropical archipelagic nation, faces a serious threat from global warming, which has caused significant climate change. The increase in global average temperatures, which has reached 1.1°C since the pre-industrial era, has impacted various aspects of people's lives, particularly the local economic sector, which is highly dependent on natural resources. In Indonesia, surface temperatures have increased by approximately 1.6°C since 1866, with projections from the Meteorology, Climatology, and Geophysics Agency (BMKG) indicating an increase of up to 3.5°C if no effective mitigation efforts are made. Eastern Indonesia, including East Nusa Tenggara (NTT), Maluku, North Maluku, Papua, and West Papua, faces a dual challenge in the context of global warming. On the one hand, this region has abundant natural resources, including fisheries, forestry, and mineral

potential. On the other hand, this region experiences significant development disparities compared to Western Indonesia, with a contribution to the Gross Regional Domestic Product (GRDP) of only 3.02 percent in 2020. This condition is exacerbated by the still high poverty rate, with Papua reaching 27.43 percent, far above the national average of 9.66 percent.

The impacts of global warming in Eastern Indonesia are manifested in various forms, from rising sea levels threatening coastal areas, to changing rainfall patterns affecting the agriculture and fisheries sectors, to an increased frequency of hydrometeorological disasters such as floods and droughts. The fisheries sector, a key pillar of the local economy, is under pressure from rising sea temperatures, which are causing coral bleaching and shifting fish migration patterns. The agricultural sector is also impacted by uncertain planting seasons and increased pest infestations due to climate change.

The people of Eastern Indonesia, who largely rely on primary sectors such as agriculture, fisheries, and forestry for their livelihoods, face high vulnerability to the impacts of global warming. Limited infrastructure, access to basic services, and weak institutional capacity further exacerbate adaptation challenges. Therefore, understanding and developing effective local economic adaptation strategies is crucial to increasing the resilience of Eastern Indonesian communities to climate change.

Research on local economic adaptation strategies to the impacts of global warming in Eastern Indonesia is urgent for several reasons. First, this region has unique geographic and socio-economic characteristics compared to other regions in Indonesia. Second, the high level of vulnerability requires a contextual adaptation approach based on local wisdom. Third, the adaptation experiences of Eastern Indonesian communities can provide valuable lessons for other regions facing similar challenges. The purpose of this research is to identify the specific impacts of global warming on the local economy of Eastern Indonesian communities, particularly in the fisheries, agriculture, and tourism sectors, and to analyze the economic adaptation strategies implemented by local communities in Eastern Indonesia in facing the impacts of global warming based on the theoretical framework of adaptive capacity.

2. RESEARCH METHODS

This study uses a qualitative approach with a literature review method to analyze local economic adaptation strategies to the impacts of global warming in Eastern Indonesia. Data were collected through a systematic review of various scientific literature sources, including academic journals, government reports, publications from international institutions such as the IPCC and BMKG, and regional development policy documents. The analysis focused on identifying the specific impacts of global warming on the local economy in the regions of NTT, Maluku, North Maluku, Papua, and West Papua, as well as the adaptation strategies implemented by local communities. Data analysis was conducted using the adaptive capacity theory framework to understand the factors influencing community adaptation capacity, including economic resources, institutions, knowledge, technology, and social capital. This study limited the use of literature to publications from the last four years to ensure the relevance and timeliness of the information, except the basic theory of adaptive capacity, which uses key references from the IPCC. The validity of the analysis was strengthened through source triangulation and comparison of findings from various literatures to ensure the consistency and reliability of the conclusions drawn.

3. RESULTS AND DISCUSSION

1. Specific Impacts of Global Warming on the Local Economy of Eastern Indonesia.

Global warming has had a significant and multidimensional impact on the local economy of communities in Eastern Indonesia. This impact is particularly felt in the economic sectors that support livelihoods: fisheries, agriculture, and tourism. These three sectors are highly dependent on climate conditions and natural ecosystems, making them highly vulnerable to climate change caused by global warming.

Impact on the Fisheries Sector

The fisheries sector is the economic backbone of the Maluku and North Maluku regions, which boast vast marine areas. The government has even established a strategy to optimize Maluku as a National Fish Barn. However, global warming has threatened the sustainability of this sector through various mechanisms. Consistently rising sea temperatures have caused fundamental changes in marine ecosystems. This has resulted in mass coral bleaching events that destroy fish habitats and reduce fisheries productivity. Coral reefs, key ecosystems for marine life, are experiencing severe degradation, which in turn threatens the entire marine food chain.

Changes in ocean temperatures are also causing shifts in fish migration patterns. Commercial fish species that were previously abundant in certain areas are now migrating to cooler waters, forcing fishermen to travel farther to achieve the same catch. This increases fishing operational costs, including fuel consumption and time spent at sea, ultimately reducing the profitability of fishing operations. Small-scale fishers, who lack capital and fishing technology, are the most affected.

Climate change also impacts production patterns in fish farming. Unpredictable changes in rainfall patterns cause fluctuations in pond water salinity, which can impact the growth and survival of farmed fish. The increased frequency of extreme weather events, such as storms and high waves, also damages pond infrastructure and causes significant economic losses. This uncertainty creates income instability for pond farmers and reduces investment in the sector.

The cumulative impact of these changes is a decline in fisheries yields and fishermen's incomes. Data shows that in several regions of Eastern Indonesia; fish catches have declined by 20-30 percent over the past decade. This not only impacts the household economy of fishermen but also threatens the food security of communities heavily dependent on animal protein from seafood.

Impact on the Agricultural Sector

The agricultural sector in Eastern Indonesia, which encompasses food crops, horticulture, and plantations, faces serious challenges due to climate change. Papua, which has significant potential to become a base for downstream processing of leading agricultural commodities, is experiencing significant disruptions to agricultural productivity due to changing climate patterns. Irregular rainfall patterns have drastically disrupted traditional agricultural cycles. Farmers are experiencing difficulty determining the appropriate planting time due to the unpredictable onset of the rainy season. This uncertainty increases the risk of crop failure.

Prolonged dry seasons, which are becoming more frequent as a result of climate change, are causing rice paddies to dry out and reducing the availability of water for irrigation. In East Nusa Tenggara (NTT), which has relatively low rainfall compared to other regions in Indonesia, drought is becoming an increasingly severe threat. Drought not only reduces crop productivity but also affects the availability of animal feed, a vital component of the agricultural system in NTT. Conversely, when the rainy season arrives, heavy rainfall can cause flooding, inundating agricultural land and damaging crops ready for harvest.

Fluctuations in temperature and increased humidity create highly favorable conditions for the growth and spread of pests and plant diseases. Pests that were previously under control are now becoming more widespread and difficult to control. Farmers must incur additional costs for pesticides and pest control, reducing profit margins. For subsistence farmers with limited access to modern agricultural inputs, pest infestations can cause total losses and threaten household food security.

The ripple effect of these agricultural disruptions is a decline in productivity and crop quality. Production of key food commodities such as rice, corn, and cassava has declined, threatening regional food security. Declining farmer incomes, a direct consequence of crop failures and rising production costs, have led to increased rural poverty. In Papua, where 27.43 percent of the population already lives below the poverty line, disruptions to the agricultural sector have worsened the economic conditions of local communities.

Impact on the Tourism Sector

The tourism sector, particularly marine tourism, a key attraction in Eastern Indonesia, is under significant pressure due to coastal ecosystem degradation. Coral reef damage due to bleaching caused by rising sea temperatures has reduced the attractiveness of diving and snorkeling destinations. Maluku and Papua, renowned for their underwater beauty, have seen a decline in tourist visits due to the degradation of coral reef quality.

Sea level rise threatens coastal tourism infrastructure, including hotels, resorts, and other supporting facilities. Increasingly frequent tidal flooding damages infrastructure and disrupts tourism business operations. Unpredictable changes in weather patterns also affect tourist comfort and the tourist season. Extreme weather, such as storms and high waves, can lead to tourism cancellations and reduced accommodation occupancy rates.

The impact on the tourism sector has not only affected large-scale tourism businesses but also local communities who rely on their livelihoods as tour guides, souvenir sellers, or tour transportation providers. A decrease in tourist visits means a decrease in income for thousands of families involved in the tourism ecosystem.

Wider Socio-Economic Impacts

The impact of global warming on productive sectors in Eastern Indonesia has a domino effect on broader socio-economic aspects. Declining income from fisheries, agriculture, and tourism reduces people's purchasing power, which in turn impacts local trade and services. Economic instability drives population migration from rural areas to cities or even beyond, which can lead to depopulation in rural areas and increase pressure on urban infrastructure.

This situation is exacerbated by the fact that the high economic growth recorded in the Maluku and Papua regions, which reached 9.25 percent in the third quarter of 2023, has not been distributed evenly to local communities. This growth is largely driven by capital-intensive downstream mining projects that do not involve much local labor. Therefore, the economic benefits of this growth are not felt by the majority of the population, who still rely on the primary sector, which is vulnerable to climate change.

Widening economic inequality resulting from the inability of local communities to adapt to the impacts of global warming poses serious social risks. Rising poverty, food insecurity, and limited access to basic services such as education and healthcare could fuel social tensions and hinder long-term development in Eastern Indonesia.

2. Local Economic Adaptation Strategy Based on the Adaptive Capacity Framework

Facing the increasingly visible impacts of global warming, communities in Eastern Indonesia have developed various economic adaptation strategies based on their

adaptive capacity. The analysis of these adaptation strategies utilizes the adaptive capacity theoretical framework, which encompasses five key dimensions: asset base, institutions and rights, knowledge and information, innovation, and organization and coordination. These strategies demonstrate the creativity and resilience of local communities in responding to the environmental changes they face.

Livelihood Diversification as an Economic Adaptation Strategy

Livelihood diversification is the most common adaptation strategy employed by communities in Eastern Indonesia to address economic uncertainty caused by climate change. In the context of adaptive capacity, this diversification reflects communities' efforts to strengthen their economic asset base by eliminating the need to rely entirely on a single, climate-vulnerable sector for income. Fishermen experiencing declining catches have begun developing seaweed cultivation as an alternative source of income. Seaweed is relatively more resistant to changes in sea temperature than some fish species and has a stable market demand.

Farmers in areas experiencing prolonged drought are shifting from water-intensive food crops to more drought-tolerant crops such as sorghum and legumes. This shift in cropping patterns demonstrates farmers' adaptive capacity to respond to changes in water availability. Some farmers are also integrating small-scale livestock farming with crop farming to create a more sustainable and climate-resilient agricultural system.

In the tourism sector, local communities affected by the decline in marine tourism visits have begun developing land-based tourism based on culture and nature as an alternative. The development of homestays and community-based tourism packages provides new income opportunities that are not entirely dependent on marine ecosystems. This diversification also creates added economic value by involving more community members in the tourism value chain.

This livelihood diversification strategy is effective in reducing household economic vulnerability to shocks caused by climate change. By having multiple income sources, communities can offset losses from one sector with income from others. However, implementing this strategy faces several challenges, including limited capital to start new businesses, a lack of skills and knowledge about alternative businesses, and limited access to markets for new products.

Utilization of Local Knowledge and Technological Innovation

Local knowledge and traditional wisdom of the people of Eastern Indonesia play a crucial role in climate change adaptation strategies. Within the framework of adaptive capacity, knowledge and information are crucial dimensions that enable communities to make informed adaptation decisions. Indigenous communities in Papua and Maluku possess traditional knowledge systems about weather patterns, planting seasons, and natural resource management that have been passed down through generations. This knowledge forms the basis for developing adaptation strategies tailored to the local context.

The practice of sasi, a local wisdom of the Maluku people in managing marine and terrestrial resources, has proven effective in maintaining the sustainability of natural resources and increasing ecosystem resilience to climate change. The sasi system regulates the timing and method of natural resource extraction to ensure sustainable regeneration. In the context of climate change, sasi practices help maintain fish and other marine stocks, ensuring that communities maintain food and income sources despite ecological pressures.

On the other hand, communities are also beginning to adopt technological innovations to increase their adaptive capacity. Using weather and climate information from the Meteorology, Climatology, and Geophysics Agency (BMKG) helps farmers

and fishermen plan their productive activities. Access to weather forecasts allows fishermen to avoid going out to sea during adverse weather conditions, thereby reducing the risk of accidents and losses. Farmers can use information about the onset of the rainy season to determine optimal planting times, thereby reducing the risk of crop failure.

Simple technologies such as drip irrigation systems and plastic mulch are being introduced in several regions to improve water efficiency during drought conditions. Floating net cage fish farming with water quality monitoring systems helps farmers anticipate changes in water salinity and temperature. While adoption of these technologies remains limited due to limited capital and access, early experiences show promising results in increasing productivity and reducing risk.

Integrating local knowledge with modern technological innovations creates a holistic and contextual approach to adaptation. However, to maximize the potential of this strategy, support in the form of training, technical assistance, and access to relevant information is needed. Local institutional capacity to disseminate knowledge and facilitate innovation adoption also needs to be strengthened.

Institutional Strengthening and Social Networks

The institutional and rights dimensions, as well as organization and coordination within the framework of adaptive capacity, are reflected in efforts to strengthen institutions and social networks at the local level. Fishermen's and farmers' groups in various regions of Eastern Indonesia play a crucial role in facilitating collective adaptation to climate change. Through these groups, members can share information about changing environmental conditions, successful adaptation practices, and access shared resources.

Customary institutions such as the sasi system in Maluku and the noken system in Papua possess strong social legitimacy and the ability to regulate community behavior in natural resource management. Revitalizing these customary institutions is a crucial strategy for improving sustainable natural resource governance in the context of climate change. Customary institutions can establish rules on no-take zones, resource extraction quotas, and sanctions for violators, which help maintain the sustainability of ecosystems and economic resources.

Local governments in several regions of Eastern Indonesia have also begun developing climate change adaptation programs involving local communities. Programs such as the construction of reservoirs to address drought, mangrove rehabilitation to protect coastal areas from abrasion and sea level rise, and the development of climate-resilient plant varieties demonstrate the government's commitment to supporting community adaptation. Coordination between the government, traditional institutions, and civil society organizations creates synergy that strengthens adaptive capacity at the local level.

Strong social networks within communities in Eastern Indonesia also serve as a social buffer mechanism during crises. Mutual assistance systems and social solidarity enable families experiencing losses due to climate disasters to receive assistance from other community members. This social capital is a crucial asset that supports community resilience to economic shocks.

However, the effectiveness of local institutions in supporting adaptation still faces various obstacles. Limited technical and managerial capacity of group administrators, limited access to funding sources, and weak coordination with the government and other external parties hinder the optimization of institutional roles. Furthermore, in some cases, conflicts between customary rules and government regulations can create legal uncertainty and reduce the effectiveness of resource governance.

Access to Financing and Insurance

One of the main obstacles to implementing adaptation strategies is limited access to financing. Within the framework of adaptive capacity, the economic asset base encompasses not only physical assets but also financial assets that enable investment in adaptation. Communities in Eastern Indonesia, predominantly low-income, face difficulties accessing formal credit from financial institutions to finance business diversification or the adoption of adaptation technologies.

Several initiatives have been developed to address this issue. Microfinance institutions and savings and loan cooperatives provide access to credit with simpler procedures and more flexible requirements than commercial banks. Government financing programs, such as the People's Business Credit (KUR) and village funds, can also be utilized to support productive businesses and climate change adaptation. However, public awareness and education about these financing schemes are still limited, leaving many people underutilizing these opportunities.

The concept of agricultural and fisheries insurance has been introduced as a mechanism to mitigate the risk of losses due to climate change. Insurance can provide financial compensation in the event of crop failure or losses due to climate disasters, thereby supporting household economic recovery. However, insurance penetration in Eastern Indonesia remains very low due to a lack of understanding of the benefits of insurance, perceived high premiums, and limited insurance services in remote areas.

To improve access to financing and insurance, intervention from various parties is needed. The government can subsidize insurance premiums for small-scale farmers and fishermen, provide revolving funds for adaptation efforts, and facilitate partnerships between financial institutions and local community organizations. Financial institutions need to develop products tailored to the characteristics and needs of communities in Eastern Indonesia, including flexible payment schemes and simplified procedures.

Value Chain Development and Market Access

Sustainable adaptation strategies require not only increased production but also access to profitable markets. Within the context of adaptive capacity, market access is part of the asset base that enables communities to convert their production into a viable income. One of the main challenges facing producers in Eastern Indonesia is the long distribution chain and the large number of intermediaries, which leads to very low prices at the producer level.

Several value chain development initiatives have been implemented to address this issue. The formation of joint venture groups allows farmers and fishermen to collectively purchase inputs and sell products directly to buyers in bulk, reducing reliance on intermediaries. The development of processing and cold storage facilities helps increase product value and extend shelf life, allowing producers to sell at more profitable times.

Digital platforms and e-commerce are beginning to be utilized to connect local producers with broader markets, including markets outside the region and export markets. Initiatives such as online marketplaces for fishery products and organic farming provide opportunities for small producers to reach consumers willing to pay premium prices for quality products. However, the adoption of digital technology remains hampered by limited internet infrastructure, low digital literacy, and a lack of trust in online transactions.

Local governments in several regions have also developed downstreaming programs for superior commodities to increase the added value of the local economy. These programs include the construction of processing facilities, skills training, and promotion of local products. However, the sustainability of these programs is often hampered by changes in political leadership and regional budget constraints.

To optimize value chain development strategies and market access, adequate infrastructure investment, including connecting roads, ports, and logistics facilities, is necessary. Human resource capacity building in business management, product standardization, and marketing is also crucial. Partnerships between local producers and large companies, research institutions, and non-governmental organizations can facilitate the transfer of knowledge, technology, and broader market access.

Barriers and Challenges to Implementing Adaptation Strategies

Although various adaptation strategies have been developed, their implementation faces a number of barriers that reduce the effectiveness of adaptation efforts. From an adaptive capacity perspective, these barriers can be categorized into five dimensions. First, limited asset bases, particularly financial capital and infrastructure, hinder investment in adaptation technologies and business diversification. Second, weak institutions and rights, including unclear land and natural resource rights, reduce incentives for long-term investment in conservation and adaptation.

Third, gaps in knowledge and information, both about climate change itself and about available adaptation options, prevent communities from making optimal adaptation decisions. Fourth, limited innovation capacity, including access to technology and the skills to adapt technology to local contexts, hinders the adoption of more effective adaptation practices. Fifth, weak organization and coordination, both within communities and between communities and external parties, reduce the ability to implement adaptation collectively and in an integrated manner.

Beyond barriers related to adaptive capacity, broader structural barriers also exist. Development policies that fail to fully incorporate climate change considerations can create maladaptation or reduce the effectiveness of community adaptation efforts. Wide economic disparities between Eastern and Western Indonesia limit the resources available for adaptation investments. Continued and increasing climate change could exceed communities' adaptive capacity, necessitating more ambitious global mitigation efforts.

The challenge ahead is how to holistically and sustainably enhance the adaptive capacity of Eastern Indonesian communities. This requires strong political commitment, adequate resource allocation, a participatory and inclusive approach, and collaboration between various stakeholders. The adaptation experiences of Eastern Indonesian communities can provide valuable lessons for developing more effective climate change adaptation policies at the national and regional levels.

4. CONCLUSIONS

Global warming has significantly impacted the local economy of communities in Eastern Indonesia, particularly the fisheries, agriculture, and tourism sectors, which are the primary sources of livelihoods. These impacts include decreased fisheries productivity due to coral bleaching and shifts in fish migration patterns, disruptions to agricultural cycles due to changing rainfall patterns and increased pest infestations, and degradation of coastal ecosystems, which reduces the attractiveness of marine tourism. These conditions are exacerbated by persistently high poverty rates and significant development disparities between Eastern Indonesia and other regions.

Communities in Eastern Indonesia have developed various economic adaptation strategies that reflect their adaptive capacity, including livelihood diversification, utilization of local knowledge and technological innovation, strengthening institutions and social networks, increasing access to finance and insurance, and developing value chains and market access. These strategies demonstrate the creativity and resilience of local communities in responding to environmental change. However, the effective

implementation of adaptation strategies remains hampered by various obstacles, including a limited economic asset base, institutional weaknesses, knowledge and information gaps, limited innovation capacity, and weak coordination among stakeholders.

To increase local economic resilience to the impacts of global warming, a holistic approach is needed that simultaneously strengthens all five dimensions of adaptive capacity. Infrastructure investment, increased access to financing, strengthening local institutions, enhancing human resource capacity, and policies responsive to community adaptation needs are essential prerequisites. Collaboration between the government, local communities, the private sector, and non-governmental organizations is necessary to implement effective and sustainable adaptation strategies. The adaptation experiences of communities in Eastern Indonesia provide valuable lessons that, despite facing limited resources, communities have the capacity to adapt if supported by appropriate policies and access to adequate resources.

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