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Management Of Coconut Plantation Land Affected By Inundation For Community Economic Resilience On Airtawar Island, Indragiri Hilir

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Abstract

Coconut plantations serve as the primary economic foundation in Indragiri Hilir Regency, which is experiencing a significant decline in productivity due to continuous seawater inundation that causes increased soil salinity, resulting in physiological damage to plants and coconut mortality. These ecological impacts trigger changes in land cover, from coconut gardens to mangrove ecosystems, which subsequently affect community socio-economic aspects. This research examines the impacts of seawater inundation phenomena on smallholder coconut plantation land changes on Airtawar Island, Indragiri Hilir. Management approaches to support local community economic resilience. The research employs a qualitative approach, utilizing literature studies and descriptive analysis, to examine the biophysical and socio-economic factors that influence these changes. Study results show that proactive management can strengthen local economic resilience. The proposed proactive management approach involves ecological integration, focusing on the management of coconut plantations and mangrove ecosystems within a single landscape management system. It also entails adaptive economic development based on local resources and stakeholder collaboration, positioning communities as the primary actors. This approach is expected to contribute to sustainable management that supports the socio-economic resilience of coastal communities by developing a holistic, multidimensional analysis.

Keywords: Inundation, Coconut Plantation, Land Change, Economic Resilience, Proactive Management

1. Introduction

Indragiri Hilir Regency stands as one of Indonesia's major coconut production centers with a recorded area of 303,556 hectares and a production of 263,732 tons, it is the only regency-level region in Indonesia that has coconut plantations covering hundreds of thousands of hectares [1]. These coconut plantations serve as the primary source of livelihood for 65,547 households of local communities, as coconuts represent a high-potential economic crop with various derivative products, making coconut plantations the economic foundation of Indragiri Hilir Regency [2,3]. Coconut plantations have contributed significantly to the formation of Indragiri Hilir Regency's Gross Regional Domestic Product (GRDP). The agricultural sector, including coconut plantations, acts as the primary contributor to Indragiri Hilir Regency's GRDP. According to the 2025 records from the Central Statistics Agency of Indragiri Hilir Regency, the GRDP derived from the agricultural sector, including coconut plantations, reached 46.25% in 2022 and 46.06% in 2024.

Geographically, Indragiri Hilir Regency encompasses the lowland areas of Sumatra Island and the surrounding small islands. The soil conditions in this region consist of alluvial or sedimentary soils with swamp and mangrove ecosystem typologies. Swamp ecosystems develop in lowland areas with wetland soils [4], while mangrove ecosystems form in coastal zones influenced by seawater salinity [5].

Smallholder coconut plantations in Indragiri Hilir are experiencing deterioration, which reduces their productivity, as seawater inundates the coconut plantation areas during high tides. During the period 2014–2023, there was a reduction of 83,517 hectares of coconut plantation area and a decline in production by 33,173 tons. In 2014, the coconut plantations covered an area of 418,963 hectares with a production of 335,446 tons, while in 2023 the area decreased to 340,941 hectares with a production of 307,768 tons. The seawater inundation phenomenon in Indragiri Hilir causes intrusion into smallholder coconut plantations, resulting in severe damage to coconuts [3,6].

Journalistic reports [6] reveal that over 1,200 hectares of residents' coconut gardens were destroyed in Sungai Bandung Hamlet, Tanjung Pasir Village, Tanah Merah Sub-district, where this hamlet is on Airtawar Island. Spatial analysis from 2024 by Eco Nusantara for Delta Indragiri Program – an initiative of landscape-based management in response to inundation phenomena – it was revealed that coconut plantations in Indragiri Hilir Regency, covering 380,680 hectares, have been identified as having 17,159 hectares severely damaged, 46,719 hectares moderately damaged, and 316,802 hectares slightly damaged to undamaged.

The damage to coconut plants caused by seawater inundation phenomena reduces land productivity, thereby worsening the economic conditions of communities that depend on coconut plantations for their livelihoods. Coconut farmers, unable to adapt to

these changes, often choose to migrate outside their region, seeking better livelihoods to alleviate economic hardship.

These conditions drive this research, which aims to formulate appropriate approaches for managing land changes in coconut plantations in Indragiri Hilir, with a study area boundary on Air Tawar Island. This focus emerges because seawater inundation phenomena, coconut plantation damage and its impacts, as well as ecosystem changes occur on Air Tawar Island, which represents one of the small islands at the Indragiri River estuary.

2. Method

This study adopts a qualitative approach employing literature review and desk study methods [7] as the primary techniques for data collection and analysis. Such an approach is considered appropriate for gaining an in-depth understanding of issues concerning the management of coconut plantations affected by inundation and their implications for the economic resilience of communities in Pulau Airtawar, Indragiri Hilir Regency. Data were obtained from scientific publications, government reports, statistical records, prior research, and other empirical documents related to coastal ecosystem changes, hydrological dynamics, coconut productivity, and socio-economic conditions. The literature search was conducted systematically through online databases.

The collected data were analyzed using descriptive-qualitative techniques [8], involving thematic and comprehensive examinations of factors influencing land degradation due to seawater intrusion, salinity shifts, land cover changes, and their socio-economic consequences. The analysis emphasized the interactions between biophysical conditions and community livelihoods, and assessed the potential for adaptive land management strategies to strengthen household economic resilience reliant on coconut-based production. This methodological framework is expected to provide a holistic perspective on the challenges and opportunities of sustainable management of inundation-affected coconut plantations in coastal Pulau Airtawar, and their broader implications for local economic resilience.

3. Results and Discussion

The seawater inundation phenomenon in coconut plantations on Airtawar Island, Indragiri Hilir, influences ecosystem changes due to salinity factors. These ecological changes impact the economic and social aspects of communities that rely on coconut commodities for their livelihoods.

3.1. Coconut Plant Damage

Coconut plantations on Airtawar Island, Indragiri Hilir, experience growth disruption and damage due to changes in water and soil salinity resulting from inundation phenomena or tidal flooding [9]. Seawater contains a high salt content, which can increase soil salinity through seawater inundation. Soil salinity poses a significant threat to agriculture, as it can significantly reduce crop yields in affected areas. Salinity changes have degraded land, resulting in decreased productivity and, in some cases, unproductive or critical land [10,11]. In coconut plantations, criticality renders land unproductive because it no longer tolerates coconut plant growth. Saline soil causes nutrient deficiency and plant toxicity. High salinity damages plant root systems, disrupts growth, and reduces production quality and quantity [12]. Plants inundated with seawater for extended periods risk experiencing water stress, root rot, and disruption of continuous growth, ultimately leading to death [13].

Coconut plant damage due to salinity changes that increase soil salinity begins with root system disruption caused by high salt content, which then triggers osmotic stress, reduces photosynthetic capacity, increases the likelihood of secondary infections, and ultimately leads to plant death. This damage is classified as physiological damage, specifically, disruption to normal tissue or plant organ functions not caused by pathogenic organisms, such as fungi or bacteria, but rather by environmental factors or cultivation management errors. Physiological damage reflects plant disease conditions resulting from non-infectious influences, which significantly impact plant survival and productivity. Causal factors include nutrient deficiency, water imbalance, and high salinity due to seawater intrusion [14-16].

Root stress in coconut plants triggers systemic chain reactions that impact the entire plant. Although plants appear alive, their functions are disrupted, so they cannot grow optimally. The impacts manifest in yellowing leaves, drying fronds, stunted fruit growth, blackening stems, and drastic production decreases. Root stress, which occurs when roots are inundated with seawater, represents the beginning of various systemic disorders in coconuts. This condition causes hypoxia (oxygen deficiency), which disrupts respiratory processes in roots. High salt content triggers osmotic stress, making it difficult for roots to absorb water. Sodium (Na^+) and chloride (Cl^-) ions, which are in salt, are also toxic and damage root cells. Roots can no longer optimally absorb water and important nutrients such as nitrogen, phosphorus, and potassium. Root damage subsequently impacts stems, causing them to lose turgor and their bases to discolor, thereby disrupting the functions of xylem and phloem. Water and nutrient transport are hindered, and stems become vulnerable to fungal and bacterial rot attacks. This disruption continues to leave fronds that yellow, dry, and then fall off, resulting in a decrease in the number of fronds due to

weakened growing points. In reproductive organs, disruptions to photosynthesis and energy supply cause flowers and bunches to fail to form or easily fall off., fruits become small, non-uniform, and may even fall before ripening. In severe conditions, plants can experience total production failure. Continuous root stress allows damage to spread until it ultimately causes the death of the crown. The entire plant canopy dries up, growing points in the apical meristem die, and plants can no longer produce new fronds. Ultimately, plants experience total death [14-18].

3.2. Land Cover Changes

The seawater inundation phenomenon on Airtawar Island, Indragiri Hilir, is suspected to be influenced by factors such as sea level rise, land surface subsidence, mangrove degradation, and damage to the water system network. The combination of these factors drives seawater to increasingly penetrate inland, exacerbating its impacts [19-22]. Prolonged seawater inundation drives changes in wetland ecosystems within coconut plantation areas, resulting in alterations to vegetation composition. This process has continued for over two decades, drastically changing the landscape structure of areas originally covered with coconuts into open, muddy land, which slowly begins to grow mangroves. Coconut plants that cannot survive in land with high salinity content become damaged and die, thus reducing their population. Mangrove species that are more tolerant of seawater inundation or saline soil conditions will begin to dominate the ecosystem. This condition drives shifts in ecosystems from coconut plantations to mangrove ecosystems. Ecological succession occurs through processes of change in ecological community structure. Land previously planted with coconuts gradually changes into potential mangrove habitat areas after experiencing natural and anthropogenic disturbances. Field observations conducted [23] have discovered ecosystem changes marked by the beginning growth of pioneer mangrove species like *Avicennia alba* (*Api-api*) dan *Sonneratia caseolaris* (*Berembang*).

3.3. Economic and Social Impacts

The economic and social impacts of soil quality degradation are examined, resulting in damage to coconut plants. This significantly decreased smallholder coconut productivity, thereby continuing to have a lasting impact on local community economic and social aspects, primarily affecting the income and economic resilience of communities that rely on coconuts as their primary source of livelihood. The Indragiri Hilir Regency Plantation Department records that during 2017-2021, smallholder coconut plantations in Indragiri Hilir Regency experienced a 47.05% decrease in production and a 43.33% reduction in productive land. In 2017, smallholder coconut production reached 592,811 tons produced from 461,310 hectares. However, in 2021, the productive coconut land area decreased to 261,435 hectares, resulting in a production of only 313,888 tons. Soil salinity changes in coconut plantation areas due to seawater flooding cause plant damage [24], causing material losses, driving livelihood transitions, and forcing residents to migrate outside of villages. Communities that have long depended on coconut garden yields experience income decreases and face economic uncertainty. Many farmers are forced to abandon their damaged land and seek alternative sources of livelihood [23].

This condition highlights the vulnerability of coastal communities to complex ecological and social crises resulting from the impacts of seawater inundation on community coconut plantations, which were previously renowned for their abundance of coconuts. These changes cause the loss of the community's primary livelihood sources, decreased access to education, and higher school dropout rates due to economic constraints. This condition could lead to structural impoverishment and a loss of local identity.

But the presence of mangroves in areas affected by seawater inundation brings changes to the local ecosystem's structure and function. Land cover that was previously coconut plantation ecosystems changes into mangrove ecosystems, which have the potential to support community economic resilience because mangroves provide benefits as habitat providers for various fish and invertebrate species [25,26]. The seawater inundation phenomenon and its impacts in Sapat Village, Indragiri Hilir [23], force communities to begin utilizing fishery products from mangrove ecosystems formed in areas that were formerly coconut plantations, including mud crabs, shrimp, and cockles. Fishery products in mangrove ecosystems, resulting from land cover changes, have become new economic sources for communities, replacing coconuts. This demonstrates that communities can develop adaptive economies in response to ecological changes in agricultural land. The same applies to Airtawar Island for communities who choose not to migrate outside their region. Communities intuitively utilize local resources to build economic resilience.

3.4. Proactive Management

The transition from coconut plantation ecosystems to mangrove ecosystems, and the resulting impacts of seawater inundation phenomena, drive the development of adaptive and sustainable management concepts. The formulated management is proactive. In ecological terms, this management approach develops landscape-based ecosystem management integration concepts, which combine coconut plantation ecosystem management (an artificial ecosystem) with mangrove ecosystem management (a natural ecosystem) into a single, sustainable landscape management system. In economic aspects, this management develops

adaptive economy concepts, which strengthen economic resilience by increasing adaptive capacity in maintaining livelihoods and developing environmentally friendly alternative economic sources. In social aspects, this management fosters collaborative management, which enhances the collaborative roles of stakeholders (multi-stakeholders) and prioritizes communities as primary actors in the management process. The formulated proactive management concept is illustrated in Figure 1.

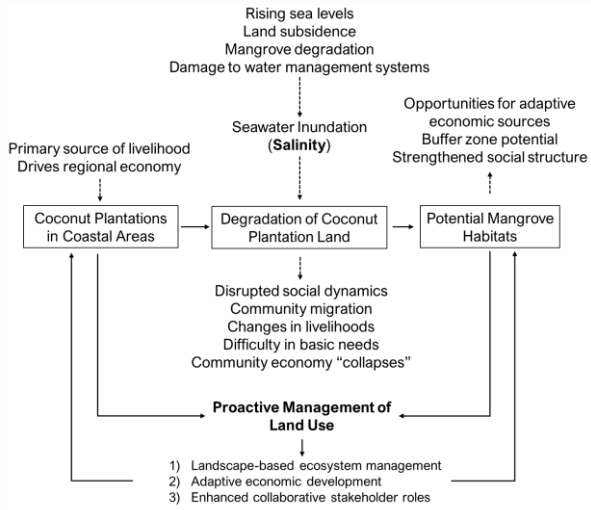

Figure 1. Proactive management concept for coconut plantation land changes affected by inundation for community economic resilience on Airtawar Island, Indragiri Hilir

The proactive management concept for coconut plantation land changes affected by inundation for community economic resilience, as in Figure 1 can be explained as:

Landscape-based ecosystem management

Integrating coconut plantation ecosystem management and mangrove ecosystem management into a single landscape management system presents a proactive alternative approach to anticipate and respond earlier to land cover changes resulting from seawater inundation. This management will also facilitate the expansion of the mangrove ecosystem to critical coconut plantation land experiencing severe damage, characterized by high salinity levels and plant damage. Coastal ecosystem rehabilitation through mangrove ecosystem improvement can enhance the protective function of mangrove forests as buffer zones. This functional enhancement can help maintain coastlines and reduce tidal current pressure on mainland areas. In the long term, this will reduce the impact of seawater inundation expansion, allowing for the protection and maintenance of coconut gardens that have not experienced severe damage.

This landscape-based ecosystem management represents an integrated approach that considers interconnections between mangrove ecosystem components and coastal mainland coconut plantations, as well as surrounding community socio-economic activities. This approach emphasizes the importance of maintaining ecological functions across administrative and ecosystem boundaries, involving various stakeholders in collaborative planning and management [25,26]. This management strikes a balance between conserving natural resources, enhancing climate change resilience, and meeting the economic needs of local communities. Landscape-based management can encompass habitat restoration, buffer zone protection, land-use control, and the strengthening of sustainable community participation.

Adaptive economic development

Approaches that communities apply in adapting to changes affecting their economic conditions represents economic adaptation strategies, which aim to strengthen economic resilience by increasing adaptive capacity, maintaining livelihoods, and developing alternative income from local resource-based economic sources [27], implemented through income source diversification, where communities depend on one type of income source and develop other potential sources as new livelihood sources [28] that are environmentally friendly, one of which is mangrove ecosystem-based capture fisheries, whose management can refer to blue economy concepts [29]. The blue economy concept represents industry development that emphasizes the innovation and creativity of owned resources, while considering exploratory, environmentally friendly economic systems aligned with sustainable economic development [30-32]. The concept of sustainable economic development is a continuous process of change that prioritizes equitable investment, focusing on technology development to meet human needs without harming natural systems. It is inclusive, environmentally conscious, and maintains environmental balance [33,34]. Blue economy development in coastal landscape areas affected by seawater inundation can focus on the sustainable utilization of mangrove potential and fisheries resources by integrating environmentally friendly fisheries and ecosystem rehabilitation. Blue economy implementation is closely tied to community survival, as most residents work as fishermen and farmers, driven by a sense of self-awareness that fosters mutual sustainability of their businesses and the environment [35]. This is achieved through effective and sustainable fishery business management [36].

In the long term, community economic activities related to coconut commodities are expected to recover gradually, along with the improvement of mangrove ecosystems as buffer zones that mitigate the impact of seawater inundation expansion. Coconut plant recovery through improved soil quality and effective water management can help re-strengthen coconut commodities as primary

economic sources for coastal communities. Additionally, communities can also develop economic diversification based on local resources.

Economic diversification represents a strategy for developing various types of businesses to create diverse income sources, thereby increasing community income and welfare while reducing dependence on specific economic sectors [37]. Through economic diversification, communities can develop alternative economic sources, thereby creating additional income streams that can help cover shortfalls from primary sources. This will provide benefits, mainly when economic disruptions occur in primary sources.

Economic diversification can enhance competitiveness and reduce dependence on a single primary economic source, while also strengthening community economic resilience and stability. This strategy can support community welfare improvement and reduce long-term economic risks. Economic diversification needs to be implemented to reduce dependence on primary economic sources [38]. Even in communities that rely heavily on primary economic sources to meet their living needs, achieving prosperity remains challenging [39]. This is because economic diversification can improve community quality of life, provide broader access to employment opportunities, lead to better income, and enhance community welfare [40].

Enhanced collaborative stakeholder roles

This land change management prioritizes the active roles of local communities as the leading actors. This management approach evolves into a participatory and adaptive approach in sustainable resource management decision-making, aligning with landscape-based sustainable management [41-44]. This approach encourages communities to become active subjects in decision-making and management actions. Local knowledge possessed by communities becomes important capital in designing adaptive management strategies, thereby encouraging the growth of responsibility, ownership, and long-term sustainability of natural resource management.

To support implementation actions, stakeholder collaboration is a crucial factor in landscape-based natural resource management. This involves cross-stakeholder cooperation, including government, local communities, the private sector, academics, and civil society organizations. These stakeholders are encouraged to build collaboration in developing aligned and sustainable action plans, ensuring they share a common perception of management vision, information sharing, and resource allocation. Collaborative stakeholder roles in ecosystem management integrate ecosystem functions across a single landscape, encompassing joint policy formulation, clear role and responsibility distribution, and joint monitoring of management actions. This approach enhances natural resource management by making it more effective, fair, and adaptable to complex socio-ecological dynamics.

3.5. Holistic Approach to Sustainable Management

The development of proactive management concepts for coconut plantation land on Airtawar Island, Indragiri Hilir, requires a holistic analysis to assess multidimensional sustainable management, thereby providing significant contributions to sustainable management. Sustainable management represents efforts to utilize natural resources in ways that do not damage the environmental capacity to support long-term life. Sustainable development represents an environmentally conscious development concept that considers environmental aspects (ecology, the environment) and development aspects, referring to efforts to harmonize economic development interests and environmental conservation [45]. In its development, this concept has generated varied thinking according to its context and interests. Sustainable management encompasses holistic and integrated approaches that consider ecological, economic, social, legal, and institutional aspects, as well as infrastructure and technological considerations. This concept development aims to increase community and environmental resilience to climate change [46].

Ecosystem-based coastal land resource management represents a management approach that does not degrade land resources, does not disturb surrounding ecosystems, provides adequate economic sources for community welfare, can contribute to the macro-scale economy, and fosters conducive social dynamics [47]. In ecological contexts, ecosystem-based land resource management targets in a single landscape aim to achieve management that fosters positive interactions between ecosystems [48]. This management concept encompasses sustainable management, which involves multiple dimensions [49].

Holistic analysis methods for sustainable management involving multiple dimensions include RAPFISH (Rapid Appraisal for Fisheries), which has been further developed into modified RAPFISH. This method is designed as a rapid tool to assess the sustainability of natural resource management using multidimensional score-based approaches, which visually and quantitatively describe the status of natural resource sustainability [49]. This multidisciplinary rapid assessment method evaluates comparative natural resource sustainability by assessing management based on numerous easily assessable attributes selected to reflect sustainability.

For holistic approaches to coconut plantation land changes in Indragiri Hilir, RAPFISH can be adapted to assess multidimensional sustainable management by modifying attributes and indicators that cover ecological, economic, social, infrastructure, and

technological, as well as legal and institutional dimensions. The ecological dimension assesses ecosystem conditions and functions that ensure resource utilization does not damage ecosystems and maintains the sustainability of environmental functions. The economic dimension assesses resource utilization activity contributions, ensuring activities run productively, profitably, and improve welfare without sacrificing future resource sustainability. The social dimension assesses welfare conditions and community participation, with social relationships dependent on resources, ensuring that resource management is applied fairly and improves community quality of life. The infrastructure and technology dimension assesses the availability, quality, and utilization of facilities, infrastructure, and technology that support efficient and sustainable resource utilization, ensuring that infrastructure and technology can increase productivity without harming the environment. The legal and institutional dimension assesses the effectiveness of rules, compliance, and institutional roles in supporting fair and sustainable resource management.

The five sustainable management dimensions will subsequently be built with attributes and indicators to assess sustainability status. Sensitive attributes become crucial factors in developing models for coconut plantation land change management on Airtawar Island, Indragiri Hilir, which enhances the economic resilience of the coastal community.

4. Conclusion

Proactive management emerges as an alternative sustainable approach to mitigating the seawater inundation phenomenon on Airtawar Island, Indragiri Hilir, which causes significant damage to coconut plantations due to increased salinity and land cover changes. This management approach focuses on integrating the management of coconut plantation ecosystems (an artificial ecosystem) and mangrove ecosystems (a natural ecosystem) within a single landscape-based management system, developing adaptive economies based on local resources, and enhancing collaborative stakeholder roles by positioning communities as the primary actors.

The proactive management approach will strengthen community economic resilience by analyzing multidimensional factors holistically, thereby requiring further research to develop a management model and design an implementable strategy based on key management factors.

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