Ilomata International Journal of Social Science
P-ISSN: 2714-898X; E-ISSN: 2714-8998
Volume 5, Issue 3, July 2024
Page No. 743-753

Cultivating Climate Solutions: Agroforestry's Potentials and Roles in North Kalimantan's REDD+ Program

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Received : May 15, 2024
Accepted : July 13, 2024
Published : July 31, 2024

Citation: Sutrisno, A., Agang, W., Hartono, T, T., Sayaza, M, D. (2024). Cultivating Climate Solutions: Agroforestry's Potentials and Roles in North Kalimantan's REDD+ Program. Ilomata International Journal of Social Science, 5(3), 743-753.
https://doi.org/10.61194/ijss.v5i3.1253

ABSTRACT: Agroforestry in North Kalimantan offers a promising avenue for balancing community livelihoods with carbon sequestration, crucial for the REDD+ initiatives. This paper examines the potential of agroforestry in North Kalimantan to support the REDD+ program, addressing both environmental sustainability and socio-economic development. Through field observations and interviews across four regencies and one city in North Kalimantan province, various agroforestry practices were identified, including improved fallows, alley cropping, scattered trees on cropland, living fences, and silvofishery. Challenges such as cultivation practices, post-harvest processing, market access, and financing were also explored. Three potential agroforestry models were proposed to enhance carbon capture while promoting local economic resilience. The paper underscores the importance of further research and community involvement to refine and expand these agroforestry approaches, offering hope for both local prosperity and global carbon reduction efforts.

Keywords: Agroforestry, REDD+, North Kalimantan, Carbon Sequestration, Sustainable Development.

INTRODUCTION

Anthropogenic climate change is widely recognized, prompting various sectors to implement measures to reduce carbon emissions. The forestry sector, particularly through deforestation, contributes approximately 17% of global greenhouse gas emissions, making it the second-largest source after the energy sector, according to the Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC). In many developing countries, deforestation, forest degradation, wildfires, and slash-and-burn practices are the primary causes of carbon dioxide emissions. The policy instrument REDD (Reducing Emissions from Deforestation and Forest

Degradation) aims to provide financial value for the carbon stored in forests, incentivizing developing countries to reduce emissions from forested lands and invest in low-emission sustainable development pathways (Joshi et al., 2010).

In Indonesia, community-based forest management initiatives are expected to support the commitment to reducing carbon emissions by 31.89-43.20%, aligned with the FOLU Net Sink 2030 target, as outlined in the Minister of Environment and Forestry Decree No. SK.168/MENLHK/PKTL/PLA.1/2/2022. North Kalimantan, facing the threat of deforestation over 405,296 hectares, including 284,695 hectares of unused or undeveloped land, presents a significant opportunity for implementing effective land-use strategies. A study indicate that nearly half of all agricultural land globally maintains at least 10% tree cover (Zomer et al., 2014). However, trees outside of forests are often overlooked in carbon potential evaluations (Foresta et al., 2015; Hairiah et al., 2011).Considering trees outside forests becomes increasingly significant with the growing demand for land for non-forestry development, leading to forest land conversion (Bednarska-Olejniczak et al., 2020; Nair et al., 2022).

Tree planting in agricultural landscapes not only improves microclimate quality but also enhances the livelihoods of surrounding farmers (Noordwijk et al., 2014) and contributes to global climate change mitigation (P. Nair et al., 2009). Even when planted at low densities, the aggregate carbon accumulation in trees can combat climate change due to their broad spatial coverage (Verchot et al., 2007), with estimates of 3–15 t C ha–1 year–1 accumulated in above-ground biomass alone (Ramachandran Nair et al., 2010).

Agroforestry schemes facilitate the integration of trees with agricultural crops or livestock, allowing farmers and forest communities to produce agricultural products, timber, and non-timber forest products (NTFPs) while protecting ecosystem functions (Jose, 2009). Agroforestry, defined as a land-use system combining woody plants with crops or livestock, involves multi-species and multi-output systems with cycles exceeding one year, offering greater ecological and economic complexity than monoculture systems (P. K. R. Nair, 1993).

The implementation of agroforestry in North Kalimantan aims to optimize food, fruit, and forage production, support soil and water conservation, improve the local environment, and enhance the socio-economic conditions of farmers, thus diversifying their income sources (Widianto & Suprayogo, 2003). Despite internal challenges such as soil fertility and labor availability, and external challenges like product price fluctuations, agroforestry provides significant environmental, economic, and social benefits, supporting climate change mitigation goals and improving community livelihoods. This paper examines the potential of agroforestry in North Kalimantan to support the REDD+ program, addressing both environmental sustainability and socio-economic development (Blomley et al., 2017; Errico, 2016; Evans et al., 2014; Guerra, 2002).

METHOD

The study was conducted across four regencies (Bulungan, Malinau, Tana Tidung, and Nunukan) and one city (Tarakan) in North Kalimantan province. Data were collected using observation and in-depth interviews, as those two are commons method to use of assessing agroforestry potentials

(Tranchina et al., 2024; Uwera et al., 2022). Descriptive analysis was applied to the data obtained from these methods. Initially, we visited and conducted interviews with each regency's and city's Forest Management Unit (FMU), or Kesatuan Pengelolaan Hutan (KPH), to understand the general condition of agroforestry practices. Subsequently, we engaged with social forestry business groups (SFBG), or kelompok usaha perhutanan sosial (KUPS), conducting in-depth interviews with their representatives. For both FMUs and SFBGs, we explored themes including: 1) plant types and crop patterns based on ecological and socio-cultural aspects, 2) marketing potential of crop commodities, 3) potential marketing chains or institutions for agroforestry products, 4) potential environmental services benefiting agroforestry managers, and 5) tenure-related obstacles faced. Additionally, we observed the lands cultivated by the communities.

RESULT AND DISCUSSION

Geographical conditions

The soil in North Kalimantan is predominantly ultisol, reflecting the common soil characteristics of Kalimantan Island. In Tarakan City, the soil is classified as ultisol with red-yellow podzolic and latosol types (Sutrisno et al., 2011). Across Kalimantan, ultisol soils cover approximately 21,938,000 ha, mostly found in karst landscapes and present in various topographies, from flat to mountainous (Subagyo et al., 2000). In North Kalimantan, karst areas span 546,103 ha, with Bulungan Regency having the largest portion, covering 312,851 ha, or about 58% of the karst area in the region (Pusat Pengendalian Pembangunan Ekoregion Kalimantan, 2016).

Social, economic, and culture condition

The potential of agroforestry practice cannot be separated by the existing conditions. The practice of slash-and-burn agriculture is still prevalent among communities in North Kalimantan. In regions like Bulungan and Malinau, it is common for land cultivators to come from outside the local area. Additionally, many locals are not motivated to plant timber trees in their yards because these trees are still readily available in the nearby forests (Brandt & Staiss, 2019).

Economically, North Kalimantan's GDP increased from 100.423 billion rupiah in 2020 to 138.718 billion rupiah in 2022, with the mining and quarrying sector contributing 36.42% and agriculture, forestry, and fisheries contributing 14.06% (BPS Provinsi Kalimantan Utara, 2023). Most commodities are sold locally, often within the same village, and rarely reach markets outside the district or province. In terms of education, most workers have only completed elementary school or less, but during the COVID-19 pandemic, the percentage of workers with only elementary education decreased while those with higher education increased (BPS Provinsi Kalimantan Utara, 2022). Institutional efforts include the formation of a Working Group by the Governor's decree No. 18844/K.118/2023, aimed at reducing emissions from deforestation and forest degradation in North Kalimantan.

Existing practices

From field observations and interviews conducted, there are at least five types of agroforestry practices that have been practiced by the community in North Kalimantan, namely:

a. *Improved fallows*

Improved fallow itself is a method that allows for the natural regeneration of vegetation and soil fertility. This method restores soil fertility faster than traditional fallow systems, shortening the fallow period. It reduces the need for fertilizers. The effectiveness of improved fallow depends on the fallow period and the species of trees planted. Improved fallow requires many shrubs with relatively short lifespans, so propagation methods should be simple and inexpensive. A mix of improved fallow species can be planted for multiple benefits, such as carbon sequestration. In terms of carbon, improved fallow and forest rotation agroforestry systems rapidly accumulate carbon (Mohan Kumar & Nair, 2011). The rotation period for improved fallows is typically around 1-2 years (Evizal & Prasmatiwi, 2021). One improved fallows practice is found in the Tarakan City by cultivating lamtoro (*Leucaena leucocephala*).

b. *Alley cropping*

This method is a practice where crops are grown between rows of trees and/or shrubs, ideally species within the legume group. This method aids in increasing land production and productivity by maintaining and improving soil moisture and fertility. However, alley cropping requires intensive management. Overall, the potential for soil carbon sequestration is much higher in alley cropping compared to monoculture agronomic systems. Several studies indicate that this cropping pattern is superior in carbon sequestration compared to monoculture cropping systems (Oelbermann, 2002; Peichl et al., 2006; Thevathasan & Gordon, 2004). Two alley cropping practices are found, one in Tarakan City utilizing eucalyptus (*Melaleuca leucadendra*) and the other in Tana Tidung Regency focusing on maize (*Zea mays*), banana (*Musa Paradisiaca*), and durian (*Durio zibethinus Murr.*).

c. *Scaterred trees on cropland*

This method involves individual tree and shrub planting in agricultural land, with perennial crops planted underneath. This practice necessitates careful management and protection of naturally growing trees and/or new plantings. Planting trees in agricultural land is often feasible, with benefits such as improved soil fertility and structure more apparent in areas with limited or no use of inorganic fertilizers. This method is practiced in Bulungan Regency, where communities grow cocoa (*Theobroma cacao*) alongside durian (*Durio zibethinus Murr.*) and elai (*Durio Kutejensis*).

d. *Living fences*

Living fences are trees or shrubs planted closely together to serve as barriers, protecting crops from livestock and human interference, typically surrounding homes and gardens. These living fences can be combined with other trees for wood and fruit production, comprising one or multiple species, offering a cost-effective method to demarcate large areas long-term, while also holding potential for carbon storage (Torres et al., 2010) and biodiversity conservation (Harvey et

al., 2004). In Nunukan Regency, the practice involves combining terap (*Artocarpus odoratissimus*), mulberry (*Morus alba*), and various fruit trees.

e. *Silvofishery*

Silvofishery is an integrated system that harmoniously combines forestry and aquaculture practices sustainably. This innovative approach aims to optimize land use by integrating trees and fish in complementary systems. Trees contribute to biodiversity, soil health, and carbon sequestration, while aquaculture components, such as fish ponds, enhance water management and nutrient recycling. This practice is being implemented in Tana Tidung regency, where the community utilize prawns (*Macrobrachium rosenbergii*) dan fish cork (*Channa striata*) with mangrove.

Potential practices for REDD+

After thoroughly examining current practices, our study introduces three innovative agroforestry models designed to support local communities while enhancing carbon capture. The first model focuses on coffee-based agroforestry, integrating coffee cultivation with lamtoro *(Leucaena leucocephala*) and durian (Durio zibethinus). The second model is eucalyptus-based agroforestry, which involves planting eucalyptus trees in combination with other tree species to maximize both ecological and economic benefits. The third model is a mangrove-based silvofishery, which combines the cultivation of mangroves with fish farming, specifically raising milkfish (*Chanos chanos*) in mangrove areas.

Each of these agroforestry models offers significant economic benefits while contributing to carbon sequestration. For instance, the coffee-based agroforestry model not only provides high-value crops but also enhances soil fertility and biodiversity through the inclusion of lamtoro and durian. The eucalyptus-based model leverages the fast-growing nature of eucalyptus trees to quickly sequester carbon, while also providing timber and other products. The mangrove-based silvofishery model is particularly noteworthy for its dual role in carbon capture and income generation, as milkfish farming in mangrove areas supports both environmental sustainability and local livelihoods.

These agroforestry approaches are designed to integrate agriculture, forestry, and fisheries, addressing both environmental and economic challenges in a synergistic manner. They align with the goals of the REDD+ initiatives by promoting sustainable land use practices that reduce emissions from deforestation and forest degradation. By adopting these models, local communities can enhance their resilience to climate change while securing multiple income streams, thereby reducing their vulnerability to market and climate fluctuations.

Beyond their economic and environmental advantages, these agroforestry models also promote biodiversity and resilience in agricultural systems. Integrating diverse crops and tree species creates habitats for beneficial insects, birds, and other wildlife, thereby enhancing ecosystem services like pollination and pest control. Furthermore, the multiple income streams generated from agroforestry products and fish farming can provide a financial buffer for communities, increasing their long-term sustainability. These integrated approaches offer holistic solutions to the complex

challenges facing rural communities, fostering both environmental stewardship and economic prosperity.

Challenges for the practices

The current practices indicate that the implementation of agroforestry holds significant promise for enhancing the effectiveness of the REDD+ program. Nonetheless, communities are encountering various challenges that impede the advancement of agroforestry initiatives, namely:

a. Cultivation challenge

A prominent cultural aspect in this region is the practice of shifting agriculture, or slash-and-burn farming, which is still common among local communities. In districts like Bulungan and Malinau, land clearing for farming is often conducted by individuals from outside these districts. Culturally, many farmers in North Kalimantan are subsistence farmers, producing primarily for their own consumption. Interviews reveal that crops such as upland rice, vegetables, and some fruits are mostly grown for personal use, with any surplus sold at local markets. There is no significant commercial farming of specialized commodities. A shift in mindset is also noted, with younger generations increasingly disinterested in farming due to better economic opportunities elsewhere. The introduction of technology presents both challenges and opportunities; for example, mechanized plowing might diminish traditional cooperative labor practices, while new machinery can enhance productivity. Additionally, issues such as the expansion of oil palm plantations and pest problems pose challenges to the development of agroforestry for REDD+ programs. The transition to monoculture palm oil plantations, favored for their economic benefits, undermines carbon sequestration efforts compared to diversified agroforestry systems.

b. Post-harvest challenge

Agricultural commodities require adequate facilities and infrastructure to produce marketable derivative products. For instance, in Antutan Village, Bulungan Regency, there is already a place for drying harvested cocoa. However, there are no machines available to process the cocoa into powder and packaging, which would significantly increase the market value of the cocoa harvest. In addition to cocoa, eucalyptus is another abundant commodity found in Tarakan. The production of eucalyptus requires infrastructure such as distillation factories. Interviews with local farmers revealed that the lack of distillation facilities directly affects the profits they can earn, as they are capable of producing higher yields. The absence of these essential facilities limits the potential for added value in their products. Thus, improving infrastructure for both cocoa and eucalyptus processing is critical to enhancing the economic benefits for the local communities. This would not only help in increasing the profitability of their harvests but also contribute to the overall development of the agricultural sector in these areas.

c. Marketing problem

The challenges in marketing are mainly due to two factors: underdeveloped soft and hard infrastructure. Hard infrastructure issues include the long distance between villages and the nearest markets, leading to high transportation costs for moving goods. This distance makes it harder and

more expensive for local producers to sell their products. Soft infrastructure problems involve the community's limited skills in marketing. These challenges include choosing target markets, packaging products, and advertising. The lack of expertise in these areas prevents the community from effectively selling their products and improving their marketing efforts. Without better infrastructure, the community will continue to struggle with successful market integration.

d. Business financing and assistance

Funding for cultivation activities typically comes from two main sources: personal funds and assistance. Personal funds usually cover the costs of purchasing seeds and fertilizers, with individuals using their own money for these expenses. On the other hand, assistance often comes from the Forest Management Unit (KPH), which supports seedling production. However, obtaining this assistance can be time-consuming because it requires obtaining the necessary permits from relevant authorities.

Strategies to address the challenges

To effectively implement the REDD+ program in North Kalimantan, it's crucial to address the identified challenges. This involves finding a balance between environmental preservation and meeting the socio-economic needs of local communities. Two key considerations are ensuring that agroforestry practices can provide subsistence and economic benefit. Subsistence involves cultivating crops within agroforestry systems to meet household food demands, thereby fostering self-sufficiency and reducing dependence on external sources. Gaining economic benefits revolves around generating income through agricultural product sales.

To achieve both considerations, three aspects must be worked on. First, aspects of land and commodity suitability. The selection of commodities based on existing land conditions is a crucial step in developing an agroforestry scheme. Considering the previously described land conditions, integrated farming that combines agriculture and livestock is necessary. To effectively implement such integrated farming, the adoption of Good Agricultural Practice (GAP) is essential. One critical component for the successful implementation of GAP, while maintaining commodity production, is proper fertilization. Simultaneously, this approach requires community capacity-building to acquire knowledge and skills, encompassing all stages from cultivation and harvesting to post-harvest processes.

Second, the socio-culture aspect. The planning of agroforestry schemes cannot be separated from the socio-cultural aspects of the community. Data collected indicates a strong tradition of shifting cultivation among the local population, characterized by the use of slash-and-burn techniques for land clearing. While this practice can be integrated into agroforestry, the increasing population will lead to a greater demand for land, potentially rendering this method less ideal in the future. As population growth continues, it will be essential to consider more sustainable land-use practices to meet the rising need for agricultural space.

Lastly, the market aspect. To effectively sell the commodities produced by farmers, good market access and conditions are essential. Achieving this requires attention to four key aspects. First, efficient supply chain integration involves collaborating with local cooperatives and processing

units, ensuring efficient harvesting, processing, and distribution, along with strict quality control. Second, obtaining certifications like FSC (Forest Stewardship Council) for wood and sustainable agriculture certifications for crops can enhance market appeal by attracting environmentally conscious consumers. Third, promoting products through digital platforms and social media, along with maintaining access to physical markets, helps reach a wider audience. Finally, forming partnerships with local businesses and restaurants can boost community engagement and increase demand for agroforestry products.

CONCLUSION

Agroforestry in North Kalimantan presents a viable strategy for balancing community livelihoods with carbon sequestration, crucial for the REDD+ initiatives. The diverse agroforestry practices observed in the region, such as improved fallows, alley cropping, scattered trees on cropland, living fences, and silvofishery, highlight the adaptability and resourcefulness of local communities in integrating trees with agricultural crops and livestock. These practices not only enhance agricultural productivity and biodiversity but also contribute significantly to carbon sequestration, aligning with global efforts to combat climate change. By refining and expanding current practices through further research and community engagement, agroforestry offers significant potential for enhancing local prosperity while contributing to global carbon reduction efforts.

Additionally, the integration of agroforestry with the REDD+ program underscores the importance of comprehensive strategies that consider both environmental conservation and economic development. Through collaborative efforts involving researchers, policymakers, and local communities, North Kalimantan can develop robust agroforestry models that provide numerous benefits, including improved livelihoods, enhanced ecosystem services, and significant carbon sequestration. This holistic approach not only aids in mitigating climate change but also fosters sustainable and resilient rural development.

We extend our sincere appreciation to the BAPPEDALITBANG of North Kalimantan, the Forest Management Units in each regency and city, and the local communities for their invaluable support during the research activity.

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