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Valuation of Cocoa Agroforestry Ecosystem Services: Impacts on Biodiversity and Farmer Income

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ABSTRACT

Cocoa agroforestry provides important ecosystem services such as biodiversity conservation, carbon storage, and support for pollination and nutrient cycling, which are often not market-valued. This study evaluates the economic value of non-market ecosystem services from local cocoa-agroforestry systems and their correlation with biodiversity and farmer income. Through a cocoa farmer survey and a contingent valuation approach, estimates of farmers' willingness to pay for the integration of shade trees in cocoa fields were obtained as a proxy for the value of ecosystem services. Results indicate that farmers value environmental services (e.g., pollinator habitat, soil fertility) at approximately IDR 2.5 million/ha/year. At the landscape level, cocoa agroforestry supports higher species richness than monoculture, with a loss of ~60% of forest species if shade trees are removed. Trade-offs appear moderate: low-shade intensification increases short-term production by ~40% but decreases carbon stocks and forest species. This study confirms that cocoa agroforestry can maintain biodiversity nearly equivalent to young secondary forests, while diversifying farmer incomes (fruit/timber). The economic valuation of ecosystem services justifies incentives (e.g., payment for ecosystem services) for farmers to maintain tree shade for the benefit of all.

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INTRODUCTION

The sustainability of cocoa farming often faces a dilemma between increasing production and environmental conservation. Cocoa agroforestry cultivating cocoa under a diverse shade tree system is believed to offer a multifunctional solution: maintaining biodiversity, carbon storage, and microclimate stability, without significantly reducing yields. However, the value of these ecosystem services is rarely quantified economically, leading farmers to shift shade to monoculture systems for short-term gains. Research in Sulawesi, Indonesia, showed that converting forests to cocoa agroforestry maintained relatively high species richness, despite a significant decline in tree biomass and forest-specific species. Conversely, intensification, which reduced shade from 80% to 40%, resulted in only a small change in diversity but doubled farmers' incomes. This raises a dilemma: how to balance farmers' economic benefits with long-term ecosystem services. This study aims to assess the economic valuation of cocoa agroforestry ecosystem services (e.g., biodiversity habitat, pollination function, etc.) and their impact on farmer incomes. It is hoped that with quantitative evidence of the monetary value of environmental services, incentive policies can be directed to encourage sustainable cocoa agroforestry practices.

RESEARCH METHOD

The study was conducted in two cocoa-producing landscapes (secondary vs. intensive forest) in Sumatra. We conducted a biodiversity inventory (shade plants, birds, ants) in cocoa plots with high vs. low shade. A participatory survey of 120 farmers recorded income from cocoa and intercropping. Ecosystem service valuation was conducted using the Contingent Valuation Method: farmers were asked about their willingness to pay (WTP) for specific shade tree addition/reduction scenarios. This approach estimates the perceived value of the benefits (e.g., pollination, natural pest control) to farmers. Trade-off analyses were conducted by comparing ecological (biodiversity score, carbon) and economic (20-year NPV, IDR) indicators across shade scenarios. Furthermore, we used literature data (e.g., PNAS Steffan-Dewenter 2007) on the impacts of cocoa intensification on ecosystem function.[3][4] Statistical techniques included logistic regression for determinants of WTP (farm size, age, environmental perception) and paired t-tests for income changes between agroforestry and monoculture.

RESULTS AND DISCUSSION

Economic Value of Ecosystem Services

Farmers are willing to pay an average of IDR 1.3–3.0 million/ha per year to maintain shade trees (mean IDR 2.2 million; ~8% of annual income). This is equivalent to the yield of two sacks of dry cocoa, indicating that farmers recognize indirect benefits such as yield stability and pollination. In aggregate, non-market ecosystem services from cocoa-agroforestry are valued at approximately USD 164/ha/year. Biodiversity: High-shaded cocoa plots have a 20–30% higher species richness index than monoculture plots (e.g., an average of 12 shade tree species vs. 2 species in monoculture). This is consistent with global meta-analyses showing that cocoa agroforestry maintains biodiversity better than open agriculture.

Farmer Income

Cocoa bean yields in moderate-intensity agroforestry (40–50% shade) are only ~10% lower than those under monoculture, but total income is higher due to by-products (fruit, firewood). Cerda et al. (2014) reported that cocoa systems with tree diversification significantly contribute to household consumption, and moderate intensification nearly doubles the return on labor.

Intensification Trade-off

Our findings are similar to those of studies in Sulawesi: excessive shade reduction increased cocoa yields by 40% but reduced carbon stocks by 75% and forest species by up to 60%. Water Use Efficiency (WUE) yields were also lower in monocultures due to uncontrolled evapotranspiration. In contrast, balanced agroforestry systems (around 30% shade) are considered the sweet spot, compromising little production for significant environmental benefits.

CONCLUSION

Valuation of cocoa agroforestry ecosystem services confirms that this system provides significant hidden economic and environmental benefits. Farmers value non-market services from cocoa-agroforestry as equivalent to ~8% of their income, demonstrating the potential of payments for ecosystem services to encourage sustainable practices. Cocoa agroforestry maintains biodiversity significantly better than monoculture without significant sacrifices to production. Farmer incomes can be increased through diversification of forest products on cocoa lands. Policy recommendations include financial incentives (a “shade cocoa” premium scheme) for farmers who maintain shade trees, as well as technical assistance to ensure optimal intensification (moderate shade, not zero). Thus, cocoa agroforestry can be a win-win solution, maintaining ecological functions (biodiversity, carbon) while sustainably enhancing the

economic resilience of smallholder farmers.

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