Preserving Riverbank Sustainability Through The Application of Agroforestry With Apiculture Type in The Bah Biak River, Tobasari Plantation, Simalungun Regency

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Abstract.

In the management of Right to Cultivate (HGU) lands, plantation companies are obligated to conserve High Conservation Value (HCV) areas, including riverbanks. However, these areas are often degraded due to encroachment and community use. This study aims to assesses the effectiveness of a community-based riverbank management model through an agroforestry system combining agro-apiculture. The actual soil erosion rate on managed riverbanks was measured and compared with that of unmanaged (vacant) land and fallow tea plantations. The results indicate a significantly lower erosion rate of 2.131 tons/ha/year, well below the national tolerable erosion threshold of 24.125 tons/ha/year. Furthermore, participating farmers earned an average of IDR 3,609,000 per month from honey production. These findings demonstrate the dual benefits of the approach—supporting riverbank ecosystem sustainability while enhancing local livelihoods offering a scalable model for sustainable HCV management in plantation landscapes

Keywords:*, Agroforestry; Conservation Value ;Erosion and Riverbank.*

I. INTRODUCTION

A watershed is a land area that forms a unified system with its rivers and tributaries, functioning to collect, store, and channel rainwater to lakes or the sea naturally. Its land boundaries are defined by topographic divides, while its seaward boundaries extend to waters still influenced by land-based activities [1]. An integral component of a watershed is the riverbank, which is classified as a High Conservation Value (HCV) Area No. 6 an area that provides essential ecosystem services, such as a water source for communities along the river. Therefore, its existence and function must be preserved and maintained by all stakeholders [2].In sustainable plantation development as required by ISPO (Indonesian Sustainable Palm Oil), plantation companies are obligated to conserve and maintain riverbanks within their concessions by preserving them as forested areas or reforesting them as part of watershed management[3]. However, implementing this intention in practice faces challenges. Unmanaged or seemingly idle riverbank areas are often occupied by local communities, creating conflicts for companies. The demand for agricultural land to improve community livelihoods also threatens the natural conservation of riverbanks [4]. Thus, riverbank management must involve local communities living nearby to ensure both environmental preservation and social harmony [5].

One alternative for managing riverbank areas is the agroforestry systeman optimal land-use approach that combines short and longterm biological production systems (integrating forestry with other biological production) [6]. This system is applied sustainably, either simultaneously or sequentially, inside or outside forest areas, with the main goal of improving community welfare [7]. Honeybees are small social insects with a highly structured division of labor, followed with remarkable discipline by all colony members [8]. Besides their unique behavior, honeybees produce honey a liquid derived from flower nectar and processed in their digestive system—which has been renowned for its health benefits since ancient times [9]. Utilizing

riverbank areas for honeybee cultivation, whether using stinging bees (Apis sp.) or stingless bees (Trigona sp.), offers an innovative solution for watershed management. This approach involves active participation from local communities living along riverbanks within plantation areas [10].

Providing farmers with seedlings of nectar-producing trees such as sugar palm, tamarind, starfruit, bridal creeper, magnolia, citrus, coconut, bay leaf, rambutan, kapok, pine, acacia, coffee, mango, calliandra, and longan—to plant along riverbanks ensures a continuous nectar supply for bees [11]. Such collaboration enables beekeepers to sustain their colonies while aligning with company-led conservation initiatives [12].Thus, reforesting riverbanks within plantation areas can restore riparian ecosystems while providing beekeepers with additional income through the production of economically valuable honey [13]. Riverbanks within plantation concessions (HGU – Right to Cultivate) must be managed sustainably according to ISPO standards. Plantation companies are required to preserve and maintain riverbanks crossing their estates, either by retaining them as forested zones or rehabilitating previously converted riverbanks [14]. However, in practice, reforested riverbanks are often occupied by local communities who perceive them as idle land. To address this, intensive community-based management is essential to conserve forested riverbanks while simultaneously providing communities with supplementary income—achievable through agroforestry systems such as beekeeping (apiculture) [15].

II. METHODS

The study was conducted from October 2023 to March 2024 in Sait Buttu Village, Sidamanik Sub-district, Simalungun Regency, North Sumatra Province, specifically at the Bah Biak Riverbank in Tobasari Plantation, Simalungun Regency, North Sumatra. The study area is located at coordinates 2.827446°N, 98.857724°E, bounded by the following: north: PTPN IV tea plantation, east: PTPN IV plantation, west: Community farmland in Sait Buttu Village, and south: PTPN IV tea plantation (Fig.1). The research site covers 22.4 hectares of the Bah Biak Riverbank within the PT Perkebunan Nusantara IV (PTPN IV) tea plantation area. This area is managed by the "TAKOMA" farmers group, which applies agroforestry practices integrated with honeybee farming (agro-apiculture).

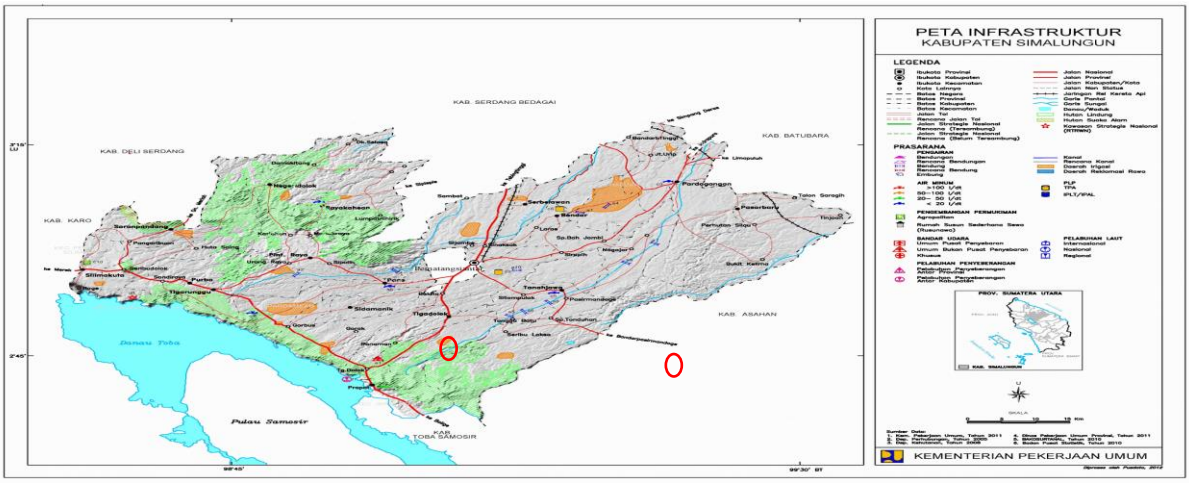

Fig 1. Maps of research location

Observation of agroforestry components

The observation of agroforestry components was conducted through direct field observations and interviews with members of the farmers' group managing the area. The observations included the following elements:

a. Types of plants
b. Number of beehives.
c. Honey production,
d. Area size

2.1. Analysis of soil physical properties

Soil quality measurements were conducted by analyzing soil samples collected from the agroforestry area integrated with honeybee farming along the Bah Biak Riverbank in Sait Buttu Village, Sidamanik Sub-district, Simalungun Regency, North Sumatra. The samples were analyzed at the **PPKS Medan Soil Laboratory**. The analysis aimed to determine the soil properties, such as organic matter content, fine sand, clay, and silt content, nitrogen (n) content, carbon-to-nitrogen (c/n) ratio, bulk density (soil weight per unit volume), soil depth, and soil permeability. These measurements provide insights into the physical and chemical characteristics of the soil in the agroforestry area.

2.2. Observation of Erosion Levels

Controlled erosion levels serve as an indicator of environmental sustainability in the riverbank area. Actual erosion levels were measured using plots measuring 5 x 10 m (10 m²) (Figure 1). Rainwater and sediment runoff were collected and measured after each rainfall event. Observation plots were established in three locations, with three replicates each open land (vacant area), tea forest (fallow tea plantation), and riverbank area (Fig. 2). The observation period lasted two months, and the data were converted to annual erosion levels based on yearly rainfall data. This approach provides a comprehensive evaluation of erosion levels across
different land-use types

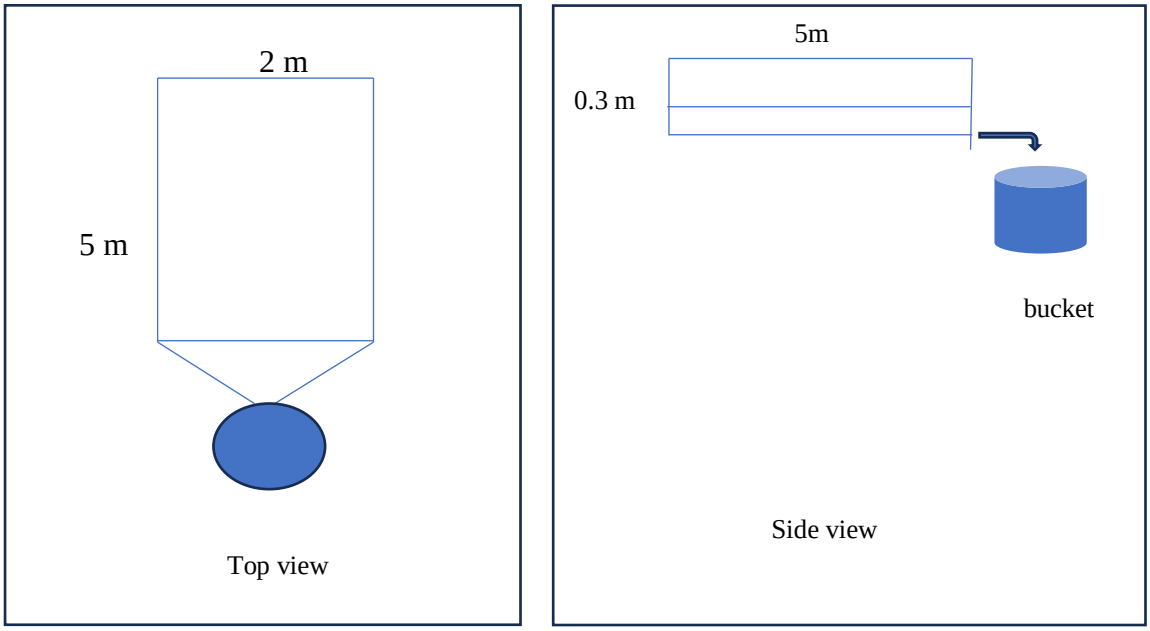

Fig 2. Erosion observation plots

Actual Erosion Results and Comparison with Permissible Erosion Levels (Edp)**.** The observed actual erosion rates were compared with the permissible erosion levels (Edp) calculated using the **Hammer Equation (1981)** in Arsyad (2010):

$$\mathbf{Edp = (KT/RL) + LPT \times BD \times 10}$$

Where:

- **Edp**: Permissible erosion level (tons/ha/year)
- **KT**: Soil depth (cm)
- **RL**: Soil lifespan (400 years)
- **LPT**: Soil formation rate (2 mm/year)
- **BD**: Bulk density of the soil (g/cm³)

This equation evaluates whether the observed erosion in the study area falls within sustainable limits, ensuring environmental stability and long-term soil conservation.

III. RESULT AND DISCUSSION

Agroforestry Components

Based on observations, the agroforestry system in the study area consists of forest plants (18 species) and agricultural crops (15 species). The details of these plant species are presented in Table 1**.**

Table 1. List of forest plants and agricultural crops in the agroforestry system at bah biak riverbank

Forest Plants		Agricultural Crops	
1	Kaliandra (Calliandra calothyrsus)	1	Coffee (Coffea arabica)
2	Sugar Palm (Arenga pinnata)	2	Tea (Camellia sinensis)
3	Dadap (Erythrina lithosperma)	3	Guava (Psidium guajava)
4	Candlenut (Aleurites moluccanus)	4	Water Apple (Syzygium aqucum)
5	Bamban (Donax canniformis)	5	Jackfruit (Artocarpus heterophyllus)
6	Jengkol (Archidendron pauciflorum)	6	Lime (Citrus x aurantifolia)
7	Cinnamon (Cinnamomum verum)	7	Lemon (Citrus limon)
8	Mindi (Melia azedarach)	8	Avocado (Persea americana)
9	Lamtoro (Leucaena leucocephala)	9	Chili (Capsicum annuum)
10	Senggani (Melastoma malabathricum)	10	Rambutan (Nephelium lappaceum)
11	Pine (Pinus sylvestris)	11	Durian (Durio zibethinus)
12	Luwingan (Ficus hispida)	12	Banana (Musa paradisiaca)
13	Clove (Syzygium aromaticum)	13	Santos (Xanthostemon chrysanthus)
14	King Fern (Cyathea contaminans)	14	Coral Vine (Antigonon leptopus)
15	Acacia (Acacia auriculiformis)	15	Dombeya (Dombeya acutangula)
16	Eucalyptus (Eucalyptus sp.)		
17	Jabon (Anthocephalus cadamba)		
18	White Teak (Gmelina arborea)		

The farmer group has replaced some forest plants with fruit-bearing agricultural crops, providing both timber and harvestable yields [16]. They have also developed honeybee farming, cultivating Apis cerana **and** Trigona itama in hives equipped with combs for easier maintenance and harvesting. This agroforestry system, combining forest plants, agricultural crops, and honeybee farming, is classified as the Agroapiculture type [17].

Soil Analysis Result

According to the national land agency (Fig.3), the type of soil at the research location is Andisol, which is a type of soil that develops from volcanic materials and is found around volcanoes. It is known as the most fertile soil type compared to others, but it is quite sensitive to erosion (Sukarman, 2014). Soil analysis results from the study and comparison sites can be seen at Table 2.

Table 2. Soil analysis results from the study and comparison sites

No.	Code	Fraction			% By Dry Weight at 105°			Permeability	Depth	Bulk desnsity
		Sand	Silt	Clay	C	N	C/N			
		%	%	%	%	%	%	Cm/hours	mm	g/Cm³
1	P0/1	64	21	15	2,87	0,32	9	0	1010	1,28
2	P0/2	62	23	15	2,06	0,25	8	1,23	1010	1,22
3	P0/3	64	23	13	3,19	0,25	13	0,64	1010	1,24
Avg.		**63,3**	**22,3**	**14**	**2,7**	**0,27**	**10**	**0,62**	**1010**	**1,25**
4	P1/1	70	17	13	5,22	0,26	20	0,64	1010	1,08
5	P1/2	54	23	23	2,33	0,23	10	7,24	1010	1,10
6	P1/3	66	21	13	2,79	0,32	9	7,24	1010	1,11
Avg.		**63,3**	**20,3**	**16**	**3,44**	**0,27**	**13**	**5,04**	**1010**	**1,10**
7	P2/1	84	13	3	3,41	0,44	8	4,45	900	1,10
8	P2/2	88	11	1	2,9	0,24	12	5,58	700	1,07
9	P2/3	80	15	5	2,94	0,28	11	3,67	800	1,07
Avg.		**84**	**13**	**3**	**3,08**	**0,32**	**10**	**4,56**	**800**	**1,08**

Keterangan : P0 = open land ; P1 = tea forest ; P2 = Bah Biak riverbank location

Table 2 shows that the soil texture in this area is dominated by sand, making the soil highly prone to erosion without the binding effect of organic matter. Additionally, the high sand content increases soil permeability, which in turn enhances its infiltration capacity. The presence of vegetation and organic matter is crucial for erosion control. The decomposition of organic matter acts as a binding agent for soil particles, forming stable soil aggregates that are less likely to break down under the impact of raindrops.

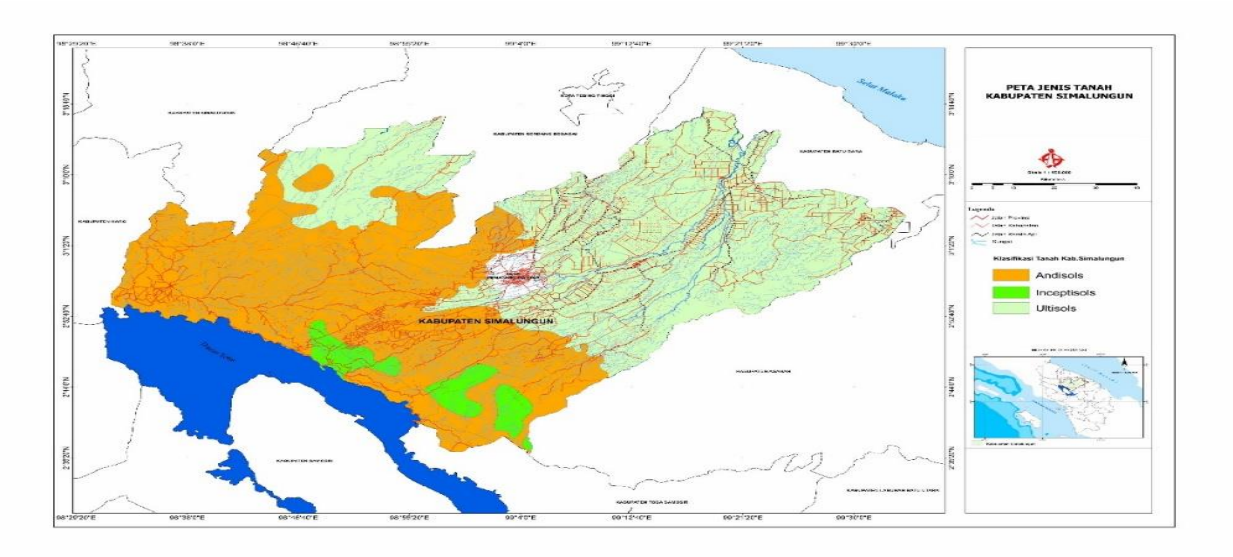

Fig 3. Soil type maps of Simalungun regency

Observed Actual Erosion Rates

The measured actual erosion rates as presented in Table 3. The **permissible erosion rate (edp) calculations can be seen in Table 4.**

Tabel 3. Measured actual erotion rates

Description	Replication	2-month rainfall	Annual rainfall	Plot area	Collected soil	Erosion rate	Remarks
		(mm)	(mm)	(M^2)	(gram)	(Ton/Ha/year)	
Open land (P0)	1	394	3074	10	2200	17,164	P0/1
	2	394	3074	10	2165	16,891	P0/2
	3	394	3074	10	2789	21,760	P0/3
Average		394	3074	10	2384,67	**18,605**	
Tea forest (P1)	1	437	3199	10	254	1,859	P1/1
	2	437	3199	10	260	1,903	P1/2
	3	437	3199	10	300	2,196	P1/3
Average		437	3199	10	271,33	**1,986**	
Agroforestry (P2)	1	629	2717	10	468	2,022	P2/1
	2	629	2717	10	487	2,104	P2/2
	3	629	2717	10	525	2,268	P2/3
Average		629	2717	10	493,33	**2,131**	

From the observed actual erosion rates (Table 3), it is evident that the erosion rate in the agroforestry area along the Bah Biak riverbank remains low at **2.131 tons/ha/year,** significantly lower than the erosion rate in open land, which is **18.605 tons/ha/year**. The combination of forest and agricultural plants in the agroforestry system reduced the soil erosion rate **by 88.55%,** while the tea forest area showed a reduction of **89.3%** compared to the erosion rate in open land. This reduction is primarily due to the presence of vegetation, which protects the soil from direct impact by raindrops, thus reducing erosion. Additionally, decomposed organic matter on the soil surface enhances soil aggregate stability, making the soil more resistant to erosion.From Tables 3 and 4, it can be observed that the actual erosion rate remains below the permissible erosion rate (Edp) in the managed riverbank area. The high Edp is attributed to the sufficient soil

depth (solum) that supports plant life and the ongoing process of rock weathering, which helps replenish soil formation, balancing the erosion rate.

Table 4. Permissible erosion rate (edp) calculations

location	Soil depth (KT)	RL (soil lifespan) (years)	Soil formation rate (LPT)	Bulk density (BD)	Permissible erosion rate (Edp) (ton/ha.year)	Criteria
P0 (Open land)	1010	400	2	1,25	27,525	High
P1 (Tea forest)	1010	400	2	1.10	24,525	High
P2 (Agroforestry)	800	400	2	1.08	24,125	High

Additional Income For Farmers From Honey Production.

Honey is the result of secretion from bees that holds significant economic value for humans and is quite expensive**.** The additional income for farmers from monthly honey sales can be seen in Table 5.

Table 5. Additional income for farmers from monthly honey sales

No	Member name	Number of beehives	Honey price	Peak income		Off-season income		Average income	
		(n)	(IDR/Kg)	(Kg)	(IDR)	(Kg)	(IDR)	(Kg)	(IDR)
1	2	3	4	5	6=5 x 4	7	8=7 x 4	9	10=9 x 4
1	Slamat Suryadi	60	180.000	50	9.000.000	28	5.040.000	39,00	7.020.000
2	Ronald Sinaga	50	180.000	40	7.200.000	22	3.960.000	31,00	5.580.000
3	Jumadi	45	180.000	35	6.300.000	19	3.420.000	27,00	4.860.000
4	Rudianto	15	180.000	12	2.160.000	7	1.260.000	9,50	1.710.000
5	Sahidin	15	180.000	12	2.160.000	7	1.260.000	9,50	1.710.000
6	Sabdi Jaya	20	180.000	18	3.240.000	10	1.800.000	14,00	2.520.000
7	Susanto	60	180.000	50	9.000.000	28	5.040.000	39,00	7.020.000
8	Peno	80	180.000	75	13.500.000	41	7.380.000	58,00	10.440.000
9	Gapet	30	180.000	25	4.500.000	14	2.520.000	19,50	3.510.000
10	Suryadi Silalahi	30	180.000	25	4.500.000	14	2.520.000	19,50	3.510.000
11	Rawatdi Sinaga	20	180.000	18	3.240.000	10	1.800.000	14,00	2.520.000
12	Tukiman	40	180.000	38	6.840.000	21	3.780.000	29,50	5.310.000
13	Setu	10	180.000	10	1.800.000	6	1.080.000	8,00	1.440.000
14	Noto	10	180.000	10	1.800.000	6	1.080.000	8,00	1.440.000
15	Tulus	15	180.000	12	2.160.000	7	1.260.000	9,50	1.710.000
16	Suparno	10	180.000	8	1.440.000	4	720.000	6,00	1.080.000
17	Pian	18	180.000	15	2.700.000	8	1.440.000	11,50	2.070.000
18	Supriadi	35	180.000	30	5.400.000	17	3.060.000	23,50	4.230.000
19	Fendi Sagala	25	180.000	22	3.960.000	12	2.160.000	17,00	3.060.000
20	Kosim	12	180.000	10	1.800.000	6	1.080.000	8,00	1.440.000
	Rata-rata				**4.635.000**		**2.583.000**		**3.609.000**

In addition to preserving the sustainability of the riverbanks, farmers also gain additional income from honey sales generated by their beekeeping activities. Table 5 shows that During the peak harvest season, farmers earn an additional income of Rp. 4,635,000 per month, while during the lean season, farmers earn an additional income of IDR. 2,583,000 per month, resulting in an average increase in farmers' income of IDR. 3,609,000**,** which is quite substantial. This income can be further increased by expanding existing bee colonies and adding more beehives.

IV. CONCLUSION

Based on the discussion above, the following conclusions can be drawn:

1. The agroforestry system implemented along the Bah Biak Riverbank is classified as the Agroapiculture type.
2. The actual erosion rate in the agroapiculture area of the Bah Biak Riverbank is 2.131 tons/ha/year, significantly lower than the permissible erosion rate of 24.125 tons/ha/year.
3. The application of agroapiculture effectively preserves the sustainability of the Bah Biak Riverbank.

4. Through the agroapiculture system, farmers gain an additional average income of IDR 3,609,000 per month.

Acknowledgment

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Conflict of Interest

The author declares that there are no conflicts of interest in this study.

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