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INTEGRATED ECOSYSTEM SERVICES VALUATION FOR CONSERVATION AREA MANAGEMENT: CARBON SEQUESTRATION, ECOTOURISM, AND BIODIVERSITY VALUES IN A REHABILITATED MINING LANDSCAPE

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ABSTRAK

Tahura Lati Petangis merupakan kawasan restorasi ekosistem bekas tambang batubara seluas 3.445,37 ha di Kabupaten Paser, Kalimantan Timur. Penelitian ini menerapkan kerangka Total Economic Value (TEV) terintegrasi yang mengkombinasikan Market Price Method, Individual Travel Cost Method, valuasi sekuestrasi karbon, benefit transfer, dan Contingent Valuation Method untuk menilai jasa ekosistem secara komprehensif. Hasil menunjukkan nilai ekonomi total sebesar Rp961,43 miliar, didominasi nilai guna tidak langsung melalui sekuestrasi karbon (Rp885,86 miliar; 92,97%), diikuti nilai non-penggunaan (Rp43,32 miliar; 4,50%) dan nilai guna langsung (Rp24,29 miliar; 2,53%). Kawasan ini menyerap 1.005.749,88 ton karbon dari 171 spesies pohon berbiomassa 775,48 ton. Keanekaragaman hayati mencakup 20 spesies mamalia, 92 spesies burung, dan 62 spesies serangga. Ekowisata mencatatkan 4.111 pengunjung (2024) dengan surplus konsumen Rp5.640.874 per kunjungan. Analisis AHP dan SWOT menempatkan kawasan pada Kuadran Pertumbuhan I, merekomendasikan pengembangan ekowisata premium, perdagangan karbon, dan pengelolaan zona penyangga terpadu. Penelitian ini menawarkan metodologi yang dapat direplikasi untuk valuasi restorasi pasca tambang dan membuktikan kelayakan ekonomi konservasi di lanskap terdegradasi.

Kata kunci: *Valuasi jasa ekosistem, restorasi pasca tambang, sekuestrasi karbon, ekowisata,*

ABSTRACT

Tahura Lati Petangis is a 3,445.37-hectare post-coal-mining ecosystem restoration area in Paser Regency, East Kalimantan, Indonesia. This study applies an integrated Total Economic Value (TEV) framework combining the Market Price Method, Individual Travel Cost Method, international carbon market valuation, benefit transfer, and Contingent Valuation Method to comprehensively assess ecosystem services. The total economic value was estimated at Rp961.43 billion, dominated by indirect use values from carbon sequestration (Rp885.86 billion; 92.97%), followed by non-use values (Rp43.32 billion; 4.50%) and direct use values (Rp24.29 billion; 2.53%). The area holds a carbon stock of 1,005,749.88 tons derived from 171 tree species with 775.48 tons of biomass. Biodiversity resources encompass 20 mammal species, 92 bird species, and 62 insect species (conservation-reference value: Rp873.42 million), while ecotourism generated a consumer surplus of Rp5.64 million per visit from 4,111 visitors in 2024. Strategic analysis using Analytical Hierarchy Process (AHP) and SWOT framework positions the area in Growth Quadrant I, prioritizing carbon trading, premium ecotourism development, and integrated buffer zone management. This study provides a replicable multi-method valuation approach for post-mining ecosystem restoration in degraded tropical landscapes.

Keywords:*Ecosystem services valuation, post-mining restoration, carbon sequestration, ecotourism.*

1. INTRODUCTION

The transformation of land degraded by mining activities into productive conservation area sis a complex challenge that requires a holistic approach to natural resource management. Coal mining, despite its significant economic contribution, often leaves an ecological footprint in the form of habitat degradation, loss biodiversity, and disruption to ecosystem function(Fauzia & Makarim, 2024; Sudarmadji & Hartati, 2023). A global review of regulatory frameworks and post-mining land use practices shows that the transition from extractive acticvities to conservation or other productive functions requires comprehensive decision-making criteria (Pagouni et al., 2024) that focus not only on the technical aspects of rehabilitation but also on long-term economic, social, and ecological dimensions.

In Indonesia, particulary East Kalimantan as one of the provinces with intensive coal mining activities, post-mining land rehabilitation faces multidimensional challenges(Hanif et al., 2025; Sudarmadji & Hartati, 2023). A literature study on coal post-mining land restoration in East Kalimantan identifies various technical obstacles such as acidic and nutrient-poor soil conditions, low availability of pioneer plant propagules, and limited understanding of natural ecological succession in tropical areas(Fauzia & Makarim, 2024). However, good practices that have been developed in southern East Kalimantan show that with an adaptive approach and the participation of local communities, post-mining land rehabilitation can achieve significant ecological success.

The United States experience in regulating and utilizing post-mining land pprovides important lessons for Indonesia. The Surface Mining Control and Reclamation Act (SMRCLA) of 1977 sets comprehensive standards for reclamation, including topographical restoration, revegetation with native species, and long-term monitoring of water and soil quality(Saputra et al., 2025). Indonesia has adopted several similar principles through Government Regulation No. 78 of 2010 on Reclamation and Post-Mining, but implementation in the field still faces challenges in terms of supervision, long-term funding, and integration with regional development programs.

One option for post-mining land use that is gaining attention is its transformation into an ecotourism destination. Research on local initiatives in Loa Ulung, East Kalimantan, demonstrates that transforming post-mining land into community-based tourism areas not only provides economic benefits but also strengthens local institutional capacity and raises conservation awareness(Hanif et al., 2025). Research on ecotourism demonstrates that visitor demographics, particularly education and income levels, significantly influence willingness to pay and visitation patterns(Silwa Al Masih et al., 2022). This approach is in line with the Sustainable Development Goals (SDGs) agenda, particularly goals 8 (Decent Work and Economic Growth), 13 (Climate Action), and 15 (Life on Land), where post-mining land policy as an ecotourism investment can be a strategy for achieving sustainable development.

The Lati Petangis Grand Forest Park (Tahura) in Paser Regency, East Kalimantan, represents a unique case study in the context of post-mining land transformation. This 3,445.37-hectare area, 58.5% (2,017.53 ha) of which was formerly a concession of PT BHP Kendilo Coal Indonesia, has undergone a rehabilitation process since mining operations ended in 2002. Its official designation as a Grand Forest Park through Decree No. 4335/MenLHK-PKTL/KUH/2015 marks the local government's commitment to preserving this area as a sustainable ecological and economic asset. Since reopening to the public in April 2025 after a period of reorganization, Tahura Lati Petangis has attracted 2,455 visitors in the first 10 days with revenue reaching Rp30 million, indicating significant ecotourism potential.

Economic valuation of ecosystem services in conservation areas is an important tool in supporting evidence-based management decisions(Costanza, 2024). The Total Economic Value (TEV) approach, which integrates direct use value, indirect use value, and non-use value, provides a comprehensive picture of the contribution of ecosystems to human well-being(García-Rubio et al., 2024; Ravi et al., 2023). However, economic valuation studies that integrate multiple ecosystem services in post-mining rehabilitation areas are still limited, especially in tropical areas of Indonesia.

Previous studies on Tahura Lati Petangis have focused on partial aspects such as tourism valuation using the Travel Cost Method, characterization of honey quality as Non-Timber Forest Products (NTFPs), and assessment of post-mining lake water quality(Anshary et al., 2023; Putra et al., 2024; Rahayu et al., 2021). There has been no comprehensive study that integrates various components of ecosystem services—ranging from carbon sequestration, biodiversity, ecotourism, to water regulation—into a holistic economic valuation framework. In fact, a comprehensive understanding of the total economic value of the area is necessary to design sustainable management strategies that can balance conservation interests with local economic development needs. In fact, a comprehensive understanding of the total economic value of the area is essential for: (1) designing sustainable management strategies that balance conservation interests with local economic development needs; (2) identifying alternative financing mechanisms such as carbon trading and payment for ecosystem services (PES); and (3) providing an empirical basis for replicating the model of transforming post-mining land into productive conservation areas in other locations.

This study fills this knowledge gap by conducting a comprehensive economic valuation of the ecosystem services of Tahura Lati Petangis using a multi-method approach. Special focus is given to three main components that have significant economic potential: (1) carbon sequestration as a contribution to climate change mitigation and carbon trading opportunities; (2) ecotourism as a source of sustainable income involving local communities; and (3) biodiversity values that reflect the biological richness of a restored tropical area. The integration of these three components into a single economic valuation framework is expected to provide a reference model for optimal and sustainable management of post-mining land-based conservation areas.

2. METHOD

2.1 Study Area

Tahura Lati Petangis is located in Batu Engau District, Paser Regency, East Kalimantan, between 116°3'40.996" E – 116°6'21.502" E and 2°2'30.786" S – 2°9'24.983" S. The conservation area covers 3,445.37 ha, definitively established through Decree SK.4335/MenLHK-PKTL/KUH/2015. The area comprises three villages (Saing Prupuk, Petangis, and Tebru Paser Damai) with a total population of 4,819 people (July 2025). The site is accessible via national paved road connecting East and South Kalimantan provinces, approximately 34 km from Paser Regency capital.

Land cover consists of 64.07% forest (secondary dry land forest and planted forest) and 35.93% non-forest areas (oil palm plantations, shrubs, and mixed gardens). The area features eight lakes (gentung), both natural and formed from former mining pits, with Gentung Dayo being the largest at 124,458.64 m^2. Climate is tropical with annual rainfall ranging from 95.8 to 444.6 mm per month, highest in January and lowest in September. Topography varies from flat to hilly, with 80.1% having flat to gentle slopes.

2.2 Data Collection

This study employs a mixed data design combining primary data (July–October 2025) with secondary data (predominantly 2020 official documentation). The rationale for this combination is as follows. Primary data were collected directly by the researcher for components requiring current revealed or stated preference information from human subjects: (1) visitor surveys (n=96) using structured questionnaires covering socio-demographic data, travel costs, visitation patterns, and willingness to pay; (2) community water-use surveys across 4 RT neighbourhoods; and (3) stakeholder interviews with conservation management staff and community representatives.

Secondary data from official DLH Kabupaten Paser documentation were used for components characterising structural ecosystem properties — flora and fauna inventories, land cover, and lake inventories — which change slowly and are assumed substantially valid over a 5-year horizon for a forest under passive conservation management. Specifically: (a) the 2020 Biodiversity Inventory Document provides the only comprehensive multi-taxa survey available, covering 36 tree species (171 individuals), 20 mammal species, 92 bird species, and 62 insect species; (b) the 2020 Lake Inventory Document (Dokumentasi Inventarisasi Danau Tahura Lati Petangis) provides the 8-lake volumetric data used for water resource valuation. Visitor count data (4,111 visitors, January–July 2025) and market price data were obtained from Tahura management records and current trade sources respectively. This mixed-source design is consistent with standard practice in ecosystem services valuation (Ignatyeva et al., 2022); the temporal mismatch between 2020 biodiversity data and 2025 conditions is acknowledged as a limitation in Section 3.7. Carbon market prices were sourced from the World Bank Carbon Pricing Dashboard 2024 and Indonesia Carbon Exchange (IDXCarbon) 2024.

2.3 Ecosystem Services Valuation Methods

2.3.1 Direct Use Value

Flora (timber) valuation employed Market Price Method using local market prices for different timber classifications (Commercial Group I & II, Ornamental Group II, and Local Wood) based on Ministry of Forestry Decree No. 163/Kpts-II/2003. Volume calculation followed the formula:

$$V = LBDS \times T \quad (1)$$

where V = volume (m^3), LBDS = basal area (m^2), T = tree height (m). Economic value was calculated as $VF = V \times P$, where P represents market price per m^3.

Fauna valuation adopted a two-tier conservation-value proxy approach, not a commercial market price. Fauna economic values in this study represent minimum legal conservation reference values for enforcement and policy purposes, not realisable revenues; commercial wildlife extraction is prohibited within Tahura as a legally protected area. Tier 1 — species with documented legal trade prices under applicable regulations (e.g., birds traded legally under PERMEN LHK P.106/2018 and Ministry of Trade Regulation No. 8/2022): actual observed market prices were applied, drawing on (Nijman, 2005) for primates and raptors price references. Tier 2 — protected species with no legal market (CITES Appendix I/II, Law No. 5/1990): price was estimated as 10% of the minimum statutory penalty under UU 5/1990 (minimum penalty Rp5,000,000/individual), representing the species' minimum legal conservation value. This approach, consistent with biodiversity conservation economics literature (Agliardi et al., 2024), reframes wildlife economic value as an indicator of ecological asset significance rather than a tradeable price. See also (Nijman et al., 2022; Siriwat & Nijman, 2020) for additional raptor price validation. Online marketplace surveys (Shopee, Tokopedia, OLX) supplemented Tier 1 price verification for legally traded common species.

Non-timber forest products (NTFP) included kelulut honey production by Forest Farmer Groups (KTH) and ecoprint products by Women Farmer Groups (KWT), valued at actual market prices.

Ecotourism valuation employed Individual Travel Cost Method (ITCM) (Jamaludin et al., 2024) following Garrod & Willis (1999). Multiple linear regression analyzed visitation frequency as function of travel costs and socio-demographic variables:

$$Vij = \beta_0 + \beta_1 Cij + \beta_2 Tij + \beta_3 Qij + \beta_4 Sij + \beta_5 Mij + \varepsilon ij \quad (2)$$

where Vij = visit frequency, Cij = travel cost, Tij = travel time, Qij = environmental quality perception, Sij = availability of substitutes, Mij = motivation level. Consumer surplus was calculated as:

$$CS = V^2 / (2\beta) \quad (3)$$

Total economic value = CS per visit × annual visitor numbers.

2.3.2 Indirect Use Value

Carbon sequestration assessment utilized the allometric equation by (Chave et al., 2014) for tropical forests:

$$AGB = 0.0673 \times (\rho D^2 H)^{0.976} \quad (4)$$

where AGB = above-ground biomass (kg), ρ = wood density (g/cm³), D = diameter (cm), H = tree height (m). Total biomass included underground biomass (AGB × 1.25). Carbon stock was calculated as 47% of total biomass, converted to CO_2 equivalents (× 3.67).

Economic valuation employed three approaches: (1)
International carbon market pricing with three scenarios: conservative (USD 5/ton), moderate (USD 15/ton), and optimistic (USD 30/ton) based on World Bank 2024 and IDXCarbon 2024 data; (2)
Replacement cost calculating number of trees required to sequester equivalent CO_2 at Rp63,699 per tree planting cost; (3)
Social Cost of Carbon (SCC) at USD 190/ton CO_2 representing long-term climate damage costs.

Water regulation services valuation used Market Price Method for household water supply from two lakes (Gentung Dayo and Gentung Duo Petangis) serving 260 households across four community groups.

Erosion prevention employed benefit transfer approach, calculating revegetation costs (RC) as sum of fertilization (F), seedling procurement (S), planting (P), and maintenance (M) costs per hectare, applied to non-forest areas (shrubs, bushes, mixed gardens, oil palm plantations).

2.3.3 Non-Use Value

Bequest and existence values were estimated using Contingent Valuation Method (CVM) with bid values ranging from Rp10,000 to Rp500,000. Willingness to Pay (WTP) (Fadillah & Juwana, 2023)was calculated as:

$$WTP = (\Sigma Wi \times Pfi) / n \quad (5)$$

where Wi = individual willingness to pay, Pfi = relative frequency, n = sample size. Total values were extrapolated to visitor population and local residents separately.

2.4 Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) following (R. W. Saaty, 1987; T. L. Saaty & Vargas, 2012) prioritized ecosystem service components through pairwise comparison matrices with consistency ratio (CR) < 0.1.

3.RESULTS AND DISCUSSION

3.1 Biodiversity Resources and Direct Use Values

Vegetation inventory identified 36 tree species with 171 individuals, dominated by Sungkai (Peronema canescens, 17.54% relative abundance) and Laban (Vitex pubescens, 12.87%). Meranti species (Dipterocarpaceae) showed highest species diversity. Timber valuation yielded Rp155.31 million, with Commercial Group I contributing 46.24% (Rp71.82 million), followed by Ornamental Group II (19.13%, Rp29.71 million), Commercial Group II (17.71%, Rp27.51 million), and Local Wood (16.92%, Rp26.27 million).

Fauna assessment documented rich biodiversity: 20 mammal species (189 individuals) with total conservation-reference value of Rp466.86 million, dominated by Sambar Deer (Cervus unicolor, VU, Rp300 million), Long-tailed Macaque (Rp34.5 million), and Smooth-coated Otter (Rp13 million). Bird diversity included 92 species, with total conservation-reference value of Rp406.56 million. Appendix I and II species (10 species, 24 individuals) were valued at Rp118.53 million using the statutory penalty proxy (Tier 2 approach), while legally traded species (23 species, 854 individuals) contributed Rp176.17 million at documented legal market prices (Tier 1). These values represent conservation asset significance for biodiversity accounting and management justification, not realisable commercial revenues (Grunewald et al., 2024). Insect inventory identified 62 species; economic valuation was not conducted due to absence of applicable pricing data.Non-timber forest products generated Rp76.13 million annually: kelulut honey (124.7 liters, Rp38.77 million) and ecoprint products (168 units, Rp37.36 million). These community-based enterprises demonstrate successful integration of conservation and livelihood enhancement.

Total direct use value reached Rp24.29 billion, with ecotourism contributing 95.43% (Rp23.19 billion), significantly exceeding biodiversity resources (3.59%) and NTFP (0.31%). This pattern aligns with global trends where non-extractive uses often provide greater economic returns than extractive uses in protected areas(Balmford et al., 2002).

3.2 Ecotourism Economics and Visitor Analysis

Visitor demographics revealed strong female representation (61%) with concentration in productive age groups: 26-35 years (31%), 36-45 years (29%), and 17-25 years (22%). Educational attainment was notably high, with 63% holding bachelor's or master's degrees and 27% completing senior high school. Income distribution showed 39% earning Rp1-3 million monthly and 31% earning Rp3-5 million, indicating middle-income target market.

Transportation patterns showed motorcycle dominance (54%) over private cars (42%), with 54% of visitors traveling 41-60 km. Tourism motivation reached 85%, with 92% having visited alternative destinations, demonstrating strong regional tourism interest. Preferred activities included scenery enjoyment (50%) and photography (22%), while lake attractions drew 63% of visitor interest, indicating over-dependence on single attraction type.

Multiple linear regression analysis ($R^2 = 0.244$, $F = 5.819$, $p < 0.001$) identified significant predictors: travel time ($\beta = 0.269$, $p = 0.003$), substitute availability ($\beta = 1.654$, $p = 0.004$), and motivation level ($\beta = 0.448$, $p = 0.017$). The travel cost variable ($\beta \approx 0.000$, $p = 0.788$) was not statistically significant, indicating that within the current narrow travel cost range of this predominantly local visitor base, this variable does not reliably identify the demand curve. This outcome is consistent with ITCM applications in settings where visitors originate from a geographically homogeneous catchment area with limited cost variation, reducing statistical power (Czajkowski et al., 2019). The model explains 24.4% of variation in visit frequency (R^2 = 0.244); this statistical limitation is acknowledged, and the consumer surplus estimate is accordingly reported as approximately Rp5.6 million per visit rather than a precise figure, to avoid implying false accuracy. Future research should apply Zonal Travel Cost Method (ZTCM) as a complementary approach and expand sample size to improve model fit.

Consumer surplus was calculated as approximately Rp5.6 million per individual per visit (precise figure: Rp5,640,874; reported as an approximation given model R^2 = 0.244), generating a total annual ecotourism economic value of Rp23.19 billion for 4,111 visitors (2024). This value substantially exceeds direct revenue from entrance fees, highlighting the importance of comprehensive economic assessment in tourism planning. The model's explanatory power should be noted as a caveat when interpreting this estimate: the significant predictors (travel time, substitute availability, and motivation) confirm that demand is present and visitor welfare is substantial, even though the travel cost coefficient did not independently identify the demand curve within this homogeneous cost range.

3.3 Carbon Sequestration and Economic Valuation

Biomass assessment using Chave et al., (2014) equation yielded 775.48 tons above-ground biomass (AGB) from 171 trees. Total biomass including below-ground component reached 969.35 tons, containing 455.60 tons carbon, equivalent to 1,672.04 tons CO_2 sequestered. Extrapolating to forest area (2,207.55 ha), total carbon stock was estimated at 1,005,749.88 tons, sequestering 3,691,102.07 tons CO_2.

Economic valuation under three carbon market scenarios produced: (1) Conservative (USD 5/ton): Rp295.29 billion; (2) Moderate (USD 15/ton): Rp885.86 billion; (3) Optimistic (USD 30/ton): Rp1,771.73 billion. Replacement cost approach, calculating trees needed to sequester equivalent CO_2 at Rp63,699 per tree, yielded Rp940.47 billion. Social Cost of Carbon method at USD 190/ton resulted in highest valuation of Rp11,220.95 billion, reflecting long-term climate damage costs.

The moderate scenario (Rp885.86 billion) was selected for Total Economic Value calculation, representing realistic market conditions based on current IDXCarbon trading prices. This conservative approach ensures credible valuation while acknowledging significant upside potential. The carbon value alone exceeds all direct use values by factor of 36, demonstrating carbon's dominant contribution to ecosystem service portfolio.

Secondary forests in post-mining landscapes demonstrate particular promise for carbon sequestration due to rapid growth rates during early succession stages (Poorter et al., 2016). The transition from degraded mining land to functional forest ecosystem over 20+ years (2002-2024) represents significant carbon accumulation, with ongoing sequestration potential as forest continues maturing.

3.4 Water Regulation and Erosion Prevention Services

Eight lakes with combined volume of 4,482,500 m^3 provide critical water storage and regulation functions. Two lakes (Gentung Dayo and Gentung Duo Petangis) directly supply 333 households across four community groups (RT), generating economic value of Rp333 million annually based on household water consumption rates and local water prices. Beyond household use, these water bodies support agricultural activities, maintain dry season flows, and provide habitat for aquatic biodiversity.

Erosion prevention services were valued using benefit transfer at Rp7.62 billion, based on revegetation costs (Rp6,369,863 per ha) applied to non-forest areas: oil palm plantations (584.8 ha, Rp3.73 billion), shrubs (406.51 ha, Rp2.59 billion), bushes (156.08 ha, Rp994.21 million), and mixed gardens (48.53 ha, Rp309.13 million). Given topography with 80.1% flat to gentle slopes and good vegetation cover, actual erosion risk remains low, but valuation reflects replacement cost if vegetation were absent.

Total indirect use value reached Rp893.82 billion, with carbon sequestration dominating (99.11%), followed by erosion prevention (0.85%) and water regulation (0.04%). This distribution reflects both the scale of carbon markets and the limited scope of current water utilization, suggesting substantial unrealized potential in water-based services development.

3.5 Non-Use Values and Community Perception

Contingent Valuation Method revealed mean WTP of Rp61,635 per individual, with weighted WTP of Rp178,486 considering frequency distribution. Participation rate reached 87.5% (84 of 96 respondents willing to pay), demonstrating strong community support for conservation. Bequest value for visitor population (4,111 people) totaled Rp21.28 billion, while local resident population (4,819 people) contributed Rp752.61 million, together yielding total existence value of Rp22.04 billion.

Non-use values comprised 4.50% of total economic value, with existence value (50.86%) slightly exceeding bequest value (49.14%). This relatively balanced distribution differs from studies in established conservation areas where existence values often dominate (Agliardi et al., 2024; Pearce & Moran, 1994), potentially reflecting the area's recent conservation status and ongoing transformation from mining landscape.

High participation rates and willingness to pay values suggest successful public recognition of conservation importance, despite majority immigrant population (from Java, South Kalimantan, Sulawesi) rather than indigenous communities. This finding challenges assumptions about sense of belonging requirements for conservation support, indicating that well-managed conservation areas can build stakeholder engagement regardless of cultural heritage connections.

3.6 Total Economic Value and Service Prioritization

Total Economic Value reached Rp961.43 billion, distributed as: indirect use values (Rp893.82 billion, 92.97%), non-use values (Rp43.32 billion, 4.50%), and direct use values (Rp24.29 billion, 2.53%). This structure demonstrates overwhelming dominance of carbon sequestration (92.14% of total TEV), followed by ecotourism (2.41%), non-use values (4.50%), and other services (1.15%).

Analytical Hierarchy Process analysis confirmed this prioritization, with carbon sequestration receiving highest weight (99.11% within indirect use values), followed by ecotourism (95.43% within direct use values). This quantitative prioritization provides evidence base for management focus on carbon market participation and premium ecotourism development.

The TEV magnitude (Rp961.43 billion or approximately USD 60 million) for 3,445.37 ha translates to Rp279 million (USD 17,400) per hectare, substantially exceeding typical oil palm plantation net present values in the region. This economic case strengthens justification for conservation-based land use in post-mining landscapes and provides template for similar restoration projects.

Table 1. Summary of Direct Use Value

No	Component	Details	Quantity	Economic Value (Rp)	% dari DUV
A	**FLORA (WOOD)**			**155.312.043**	**0,64%**
	Commercial Group One	15 species	67 trees	71.821.195	46,24%
	Commercial Group Two	3 species	31 trees	27.512.440	17,71%
	Ornamental Group Two	2 species	36 trees	29.705.956	19,13%
	Local	16 species	37 tress	26.272.452	16,92%
B	**FAUNA**			**873.419.200**	**3,59%**
	Mamals	20 species	189 individuals	466.855.000	53,45%
	Appendix I & II Birds	10 species	24 individuals	118.526.400	13,57%
	Traded Birds (Legal)	23 species	854 individuals	176.170.000	20,17%
	Other Birds	59 species	265 individuals	111.867.800	12,81%
	Insects	62 species	-	-	-
C	**NON-TIMBER FOREST PRODUCTS**			76.130.000	0,31%
	Kelulut Honey	KTH	124,7 litres	38.770.000	50,93%
	Ecoprint	KWT	168 units	37.360.000	49,07%
D	**NATURE TOURISM (ITCM)**			23.189.633.151	95,45%
	Consumer Surplus/Individual	96 respondents	4.111 visitors	5.640.874/person	-
	Annual Economic Value	278 visits	2024	23.189.633.151	-
			TOTAL DUV	**24.294.494.394**	**100%**

Table 2. Summary of Indirect Use Value

No	Component	Valuation Method	Key Parameters	Economic Value (Rp)	Description
A	**CARBON SEQUESTRATION**				
	Total Biomass (AGB)	Chave et al. 2014	775,48 tonnes	-	171 trees
	Total Carbon Stock	47% biomass	1.005.749,88 tonnes C	-	2.207,55 ha
	Total CO_2 Absorbed	3,67 × carbon	3.691.102,07 tonnes CO_2	-	-
	Conservative Scenario	Internasional Market	USD 5/tonne	**295.288.165.859**	World Bank 2024
	Moderate Scenario	Internasional Market	USD 15/tonne	**885.864.497.576**	IDXCarbon 2024
	Optimistic Scenario	Internasional Market	USD 30/tonne	**1.771.728.995.152**	Premium price
	Replacement Cost	Planting Cost	14.764.408 trees	**940.472.507.199**	@Rp 63.699/tres
	Social Cost of Carbon	SCC Method	USD 190/ton	**11.220.950.302.670**	Damage cost
B	**WATER MANAGEMENT**	Market Price Method		**333.000.000**	
	Water Resources	8 Resevoirs/Lake	4.482.500 m³	-	Total Volume
	Water Utilisation	4 RT	260 households	333.000.000	Domestik Water
C	**EROSION PREVENTION**	Benefit Transfer		7.617.845.961	
	Revegetations Costs	Per hectare	Rp 6.369.863/ha	-	F+S+P+M
	Shrubs	406,51 ha	-	2.589.412.805	-
	Scrub	156,08 ha	-	994.208.139	-
	Mixed Plantation	48,53 ha	-	309.129.427	-
	Palm Plantation	584,8 ha	-	3.725.095.590	-
			TOTAL IDUV (Moderat)	**893.815.343.537**	**97,37%**

Table 3. Summary of Non-Use Value

No	Component	Method	Parameter	Value (Rp)	% of Non-Use
A	**BEQUEST VALUE**	CVM - WTP		**21.284.188.625**	**49,14%**
	Total WTP Respondents	-	Rp5.917.000	-	-
	Number of Respondents	-	96 orang	-	-
	Mean WTP	Simple average	Rp61.635,42	-	-
	Weighted WTP	Frekuensi relatif 2,896	Rp178.485,89	-	-
	Participation Rate	Bersedia bayar	87,5% (84 orang)	-	-
	Visitor Population	2024	4.111 orang	21.284.188.625	-
B	**EXISTENCE VALUE**	CVM - WTP		**22.036.796.708**	**50,86%**
	Visitor Population	-	4.111 people	**21.284.188.625**	96,59%
	Weighted WTP	-	Rp 178.486/people	-	-
	Proportion WTP	-	87,50%	-	-
	Local Population	-	4.819 people	**752.608.083**	3,41%
	3 Surrounding Villages	-	1.755 Households	-	-
			TOTAL NON-USE VALUE	**43.320.985.333**	**100%**

3.7 Comparative Analysis and Methodological Contributions

This study advances ecosystem services valuation methodology in several dimensions. First, integrated TEV framework application to post-mining landscape fills critical research gap in Indonesian context, where most valuations focus on pristine forests rather than rehabilitated areas. Second, multiple carbon valuation approaches (market pricing, replacement cost, social cost) provide robust range of estimates rather than single-point values, acknowledging uncertainty inherent in emerging carbon markets. Third, combined application of ITCM for ecotourism and CVM for non-use values enables comprehensive benefit assessment spanning use and non-use categories.

Compared to similar Indonesian studies, TEV per hectare (Rp279 million) exceeds typical values for production forests (Rp50-100 million per ha) but remains below pristine rainforest valuations (Rp400-600 million per ha), consistent with intermediate restoration status. Carbon stock (455.6 tons C per ha) aligns with secondary tropical forest ranges (200-600 tons C per ha) reported by (Lv et al., 2025; Pan et al., 2011; Sha et al., 2022), supporting sequestration rate assumptions.

Ecotourism consumer surplus (Rp5.64 million per visit) substantially exceeds entrance fee revenue, demonstrating classic consumer surplus phenomenon where visitors derive value exceeding actual expenditure. This finding reinforces arguments for reinvestment of carbon and ecotourism revenues into conservation management rather than pure revenue extraction (Rahimian et al., 2025).

Methodological limitations include: (1) spatial sampling constraints limiting tree inventory to accessible areas; (2) fauna valuation reliance on 2020 inventory data rather than concurrent assessment — the 2020 DLH Paser Biodiversity Inventory is the most recent comprehensive survey available, and no updated full-census inventory was conducted between 2020 and 2025; the temporal gap is acknowledged and the 5-year passive conservation context mitigates but does not eliminate the risk of species composition change; (3) fauna economic values reflect conservation-proxy reference values under the two-tier approach, not commercial market prices — these figures are appropriate for conservation investment justification and biodiversity accounting but should not be interpreted as realisable revenues; (4) ITCM model fit is limited ($R^2 = 0.244$) with non-significant travel cost coefficient ($p = 0.788$), reflecting low cost variation among a geographically homogeneous visitor base; the consumer surplus estimate consequently carries substantial statistical uncertainty, and future studies should apply ZTCM and expand sample size; (5) carbon sequestration rates are based on biomass snapshot rather than longitudinal measurements; (6) CVM vulnerability to hypothetical bias in willingness to pay responses; (7) benefit transfer assumptions for erosion prevention lacking site-specific cost verification. Future research should address these through expanded field sampling, longitudinal carbon monitoring, concurrent fauna inventory, and ground-truthing of transferred values.

3.9 Policy Implications and Scalability

Research findings generate several policy-relevant insights. First, demonstrable economic superiority of conservation-based land use (Rp279 million per ha) versus extractive alternatives provides evidence for post-mining land allocation decisions. Indonesia's mining regulations require reclamation and post-mining land use planning; this study quantifies conservation option benefits, informing regulatory implementation (Dixon, 2006).

Second, carbon market participation offers significant revenue potential (Rp50+ billion projected three-year target) that could finance management operations while reducing government budget dependence. With Indonesia's commitment to carbon neutrality by 2060, conservation areas serving as carbon sinks gain strategic importance beyond local ecosystem benefits (Zhang et al., 2023). Third, ecotourism's dominant contribution to direct use values (95.43%) supports investment in visitor facilities and services as economically rational management strategy. However, single-attraction dependence (63% lake focus) presents sustainability risk requiring diversification through activity expansion and alternative attraction development.

Fourth, high willingness to pay (87.5% participation) despite majority immigrant population challenges conventional wisdom linking conservation support to indigenous cultural connections (Rahimian et al., 2025). This suggests effective conservation communication and community engagement can build stakeholder support regardless of heritage background. Methodology scalability to other post-mining sites requires consideration of: (1) site-specific biomass equations if wood density data available; (2) local market price surveys for timber and fauna; (3) visitor survey adaptation to local context; (4) carbon market price updates reflecting current IDXCarbon conditions; (5) ground-truthing of benefit transfer values. With these adaptations, the integrated TEV framework provides replicable template for post-mining restoration economic assessment across Indonesia's extensive mining landscape.

4. CONCLUSION

This study demonstrates substantial economic value (Rp961.43 billion) of ecosystem services in post-mining conservation landscape, dominated by carbon sequestration (92.14%), followed by ecotourism (2.41%), non-use values (4.50%), and other services (1.15%). Integrated Total Economic Value framework combining Market Price Method, Individual Travel Cost Method, carbon market valuation, benefit transfer, and Contingent Valuation Method provides comprehensive assessment across use and non-use categories. Carbon sequestration potential (1,005,749.88 tons carbon stock, 3,691,102.07 tons CO_2) offers significant revenue opportunity through Indonesia Carbon Exchange participation, with moderate scenario valuation of Rp885.86 billion. Ecotourism demonstrates strong performance with consumer surplus of Rp5,640,874 per visit and total annual value of Rp23.19 billion for 4,111 visitors, supported by favorable demographics (63% university educated, 70% middle-income). Biodiversity resources comprise 36 tree species, 20 mammal species, 92 bird species, and 62 insect species, with total economic value of Rp1.10 billion. Non-use values (bequest and existence) totaling Rp43.32 billion reflect strong community support (87.5% participation in willingness to pay) despite majority immigrant population. Strategic analysis positions Tahura Lati Petangis in Growth Quadrant I, recommending priority strategies: premium ecotourism development leveraging biodiversity and water resources, carbon trading implementation through IDXCarbon, rehabilitation showcase converting degraded land into conservation success story, integrated buffer zone management with adjacent land users, and institutional capacity strengthening through specialized recruitment and certification. Research contributions include: (1) integrated TEV methodology for post-mining landscapes addressing Indonesian research gap; (2) multiple carbon valuation approaches providing robust estimate ranges; (3) quantitative evidence of conservation-based land use economic superiority (Rp279 million per ha); (4) replicable framework for similar restoration projects across Indonesia's extensive mining areas. Future research should address: expanded spatial sampling for improved biomass estimates, longitudinal carbon sequestration monitoring, concurrent fauna inventory, ground-truthing of benefit transfer values, and assessment of carbon market revenue reinvestment impacts on management effectiveness. Methodology scalability requires site-specific adaptations but provides template for post-mining ecosystem services valuation across diverse contexts.

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