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Analisis Kelayakan Finansial Proyek Restorasi Hutan Mangrove Berbasis Kredit Karbon (Studi Kasus: Mahkota Mangrove Indonesia, Indramayu, Jawa Barat)

Financial Feasibility Analysis Of Carbon Credit-Based Mangrove Forest Restoration Project (Case Study: Mahkota Mangrove Indonesia, Indramayu, West Java)

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Abstract
This study aims to fill the gap in the financial feasibility study of FOLU-based carbon projects by using a case study of a carbon credit-based mangrove forest restoration project initiated by Mahkota Mangrove Indonesia (Mangrovin) in Indramayu, West Java in an area of 340 hectares. A descriptive quantitative approach is used in this study by applying financial modeling methods, including Net Present Value (NPV), Internal Rate of Return (IRR), and Discounted Payback Period (DPBP). Data were obtained through primary and secondary sources. Common allometric equations from Komiyama et al. (2005) are used to calculate the carbon sequestration potential which is then converted into carbon credits considering project emissions and uncertainty buffers. Cash flows for 30 years are projected using discounting based on WACC. The results of the analysis show strong financial feasibility with an NPV of IDR 223 billion, an IRR of 29.18%, and a DPBP of 7 years. It is known that WACC and revenue factors have the greatest influence on NPV based on sensitivity analysis. A change of ±20% WACC has impact of 30.9% and -23% on NPV, meanwhile revenue factors have an impact of ±24.1%-24.5% on NPV.
Keywords: *Carbon Credits, Mangrove Restoration, Financial Feasibility.*

ABSTRAK
Penelitian ini bertujuan untuk mengisi gap pada studi kelayakan finansial proyek karbon berbasis FOLU dengan menggunakan studi kasus proyek restorasi hutan mangrove berbasis kredit karbon yang digagas oleh Mahkota Mangrove Indonesia (Mangrovin) di Indramayu, Jawa Barat seluas 340 hektare. Pendekatan kuantitatif deskriptif digunakan dalam penelitian ini dengan menerapkan metode pemodelan finansial, meliputi Net Present Value (NPV), Internal Rate of Return (IRR), dan Discounted Payback Period (DPBP). Data diperoleh melalui sumber primer dan sekunder. Persamaan allometrik umum dari Komiyama et al. (2005) digunakan untuk menghitung potensi penyerapan karbon yang kemudian dikonversi menjadi kredit karbon dengan mempertimbangkan emisi proyek dan penyangga ketidakpastian. Arus kas selama 30 tahun diproyeksikan menggunakan diskonto berdasarkan WACC. Hasil analisis menunjukkan kelayakan finansial yang kuat dengan NPV sebesar Rp 223 miliar, IRR sebesar 29,18%, dan DPBP selama 7 tahun. Diketahui bahwa faktor WACC dan pendapatan memiliki pengaruh terbesar terhadap NPV berdasarkan analisis sensitivitas. Perubahan WACC sebesar ±20% mempunyai dampak sebesar 30,9% dan -23% terhadap NPV, sedangkan faktor pendapatan mempunyai dampak sebesar ±24,1%-24,5% terhadap NPV.
Kata Kunci: Kredit Karbon, Restorasi Mangrove, Kelayakan Finansial.

1. Introduction

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Collective cooperation has been confirmed through the Paris Agreement at the Conference of the Parties (COP) 21 in December 2015 in Paris to overcome climate issue around the world. This agreement is an international legal instrument that is legally binding so that it must be obeyed by all participants. Indonesia demonstrated its participation in the mission to reduce GHG by ratifying the Paris Agreement through Law No. 16 of 2016, which was enacted on October 25, 2016. This ratification demonstrated Indonesia's readiness to deliver and implement Nationally Determined Contributions (NDC). Indonesia increased its GHG emission reduction target from 29% to 31.89% with its own efforts and from 41% to 43.20% with international support by 2030 in the Enhanced NDC (Republik of Indonesia, 2022).This commitment has five priority sectors, namely: energy, waste, Industrial Processes and Product Use (IPPU), agriculture, and Forestry and Other Land Uses (FOLU). The FOLU sector is recorded as the largest contributor to the emission reduction target, which is around 59% of Indonesia's total target. In order to achieve the target in the ENDC, Indonesia is developing various policy instruments, including carbon market mechanisms.

Presidential Regulation No. 98 of 2021 about *Penyelenggaraan Nilai Ekonomi Karbon (NEK)* is stipulated as the legal protection for the implementation of carbon trading in Indonesia. For the forestry sector, the technical regulations for its implementation are regulated in the Regulation of the Minister of Environment and Forestry (*Permen LHK*) No. 21 of 2022. This ministerial regulation is a key instrument in carbon-based ecosystem restoration projects, including mangrove forest restoration.

Mangrove forests can directly support the achievement of ENDC in the FOLU sector because they can absorb carbon five times greater than other tropical forests (Bhowmik et al., 2022). But unfortunately, mangrove forests in Indonesia continue to experience degradation. In 2000, Indonesia was estimated to have 32,249.53 km^2 of mangrove forest, then decreased to 30,005.535 km^2 in 2020 (Hamilton & Presotto, 2024). This means that there has been a decrease of around 6.96% during that period or 0.35% per year.

In contrast to government ambitious target, there is a real gap between the projected contribution of the FOLU sector and the reality on the ground. The National Registry System for Climate Change Control (SRN-PPI) noted that from all sectors, there were 6,116,830 tons of verified CO_2. Ironically, there was only 1 project from the waste sector, 5 projects from the energy sector, and none from the FOLU sector. Based on Verra (2025), of all the projects they handle, only 1 project in Indonesia from the AFOLU sector is in the verification process, and 3 projects have just registered status. In fact, there are 20 projects from the AFOLU sector that have been registered. This shows the less-than-optimal FOLU sector in climate change mitigation actions and indicates the complexity of the issuance process.

The value of GCM in 2023 reached USD 948.72 billion. Many countries have given incentives to Companies and launched Emissions Trading Systems (ETS) to encourage investment in meeting climate targets with low-carbon technologies. The European Union ETS is the world's most valuable carbon market with a share of 87% of the global total (Twidale, 2024). This shows how big and valuable GCM is. Seeing the high carbon absorption of the mangrove ecosystem and the potential for developing the carbon market value, Mahkota Mangrove Indonesia (Mangrovin) sees an opportunity to contribute to reducing emissions as climate change mitigation while opening up potential new funding sources. Mangrovin is developing a 340-hectare mangrove forest restoration in Indramayu, West Java, which not only aims to restore the ecosystem but also generate carbon credits that can be sold on the carbon market.

The mangrove forest restoration project being planned by Mangrovin is designed with a hybrid funding scheme, which combines 50% financing from internal equity and 50% from carbon credit buyers who are willing to pay upfront. In this scheme, buyers receive benefits in the form of carbon credit allocation in the third year after the issuance process for the amount that has been paid, calculated based on the carbon price at the time of the transaction. In this project, planting activities will focus on three main species of the genus Rhizophora, namely *Rhizophora apiculata*, *Rhizophora mucronata*, and *Rhizophora stylosa*. The planting composition is planned proportionally with details of 30% *R. apiculata*, 20% *R. mucronata*, and 50% *R. stylosa*.

The carbon-based mangrove forest restoration project that will be carried out by Mangrovin is not free from threats. The unstable carbon price and competition with projects from the other sector are factors that must be taken into account. However, there are also opportunities that can be a basis for trying to get this project going. Global trends, such as the increase in carbon prices in China and the Carbon Border Adjustment Mechanism (CABM) (daunplus, 2025) shows the potential for increasing market demand for carbon credits. Indonesia is also preparing to open a carbon exchange in the FOLU sector which is projected to be worth IDR 258 billion per year (Timorria, 2025).

A study conducted by Li & Martino (2024) analyzed the economic feasibility of a saltmarsh restoration project in Scotland based on carbon credits. The results showed that the project could be profitable if the carbon price is high enough and the implementation costs are low. The study of Jakovac et al. (2020) on carbon pricing was conducted in the context of 90% of the remaining global mangrove forest. The authors suggest that a carbon price of between 3.0 and 13.0 US$ per tCO2 is needed to conserve remaining mangroves based on the opportunity costs from most land uses threatening mangroves. Meanwhile, a study conducted by Vázquez-González et al. (2017) found that the Net Present Value of mangrove carbon offsets profit is equal to $5,822.71 during a 30-year-carbonoffset contract. This shows that carbon offset projects can be profitable projects that are worth considering.

In environmental finance, there are currently few studies that combine quantitative financial approaches with real project contexts (Tao et al., 2022), especially those that specifically discuss carbon credit-based mangrove forest restoration. Although the studies that have been conducted have made important contributions to understanding the economic potential of carbon credits, none have explicitly examined carbon-based mangrove restoration projects with a detailed financial feasibility approach. This research is written to fill this gap, with a real case study of a mangrove restoration project by Mangrovin in Indonesia. With a contextual project-based approach, this study makes a unique contribution to the development of applicable environmental finance studies in the Southeast Asia region.

2. Literature Review

Carbon Cycle and Nature-Based Solution

Carbon must be continuously recycled and will be reused. Carbon recycling occurs through the carbon cycle which is a process where carbon in the earth's atmosphere, geosphere, biosphere, and hydrosphere exchanges and moves (Shabrina & Nursa'adah, 2024). The carbon cycle acts as a renewable source for biomass synthesis. Unfortunately, this cycle is disrupted by anthropogenic activities that increase CO2 levels. This increase in emissions causes changes in the earth's surface temperature which is one of the main causes of climate change. Nature-based solutions (NbS) can be a solution to the problem of carbon emissions because they utilize the natural ability of ecosystems to absorb and store carbon from the atmosphere biologically.

According to Lovelock et al. (2024), nature-based solutions are conservation initiatives that address climate change issues by protecting, managing, and restoring the environment while providing real and sustainable benefits to the community. Mangrove ecological knowledge can and should be used to design and implement nature-based solutions projects effectively. CO2 emissions from anthropogenic activities can be absorbed in large quantities by mangroves, so mangroves have an important role in climate regulation (Alongi, 2014). This raises awareness of the importance of preserving and restoring mangrove ecosystems as carbon-rich ecosystems to be nature-based solution.

Mechanisms of Carbon Sequestration in Mangroves

Mangrove forests absorb and store carbon in three main components, namely aboveground biomass (ABG), belowground biomass (BGB), and in the soil. Calculation of carbon absorption estimates for ABG and BGB can be done using the common allometric equation 1 and 2 (Komiyama et al., 2005), while for carbon in the soil, the study of Vázquez-González et al. (2017) showed that the ratio was 82% of the total biomass.

$$AGB = 0.251\ \rho\ D^{2.46} \qquad (1)$$

$$BGB = 0.199\ \rho^{0.899}\ D^{2.22} \qquad (2)$$

Where:
ABG = Aboveground Biomass
BGB = Belowground Biomass
D = Diameter at Breast High in cm, with 0,67 cm per year growth (Rahmat & Sarno, 2015)
ρ = wood density in g·cm-3 (The wood density values of various mangrove species are presented in Fig 1

Mangrove species	Wood density (g/cm³)
Avicennia marina	0.732
Bruguiera cylindrica	0.810
Bruguiera gymnorhiza	0.741
Heritiera Littoralis	0.885
Rhizophora apiculata	0.881
Rhizophora mucronata	0.848
Rhizophora stylosa	0.940
Sonneratia caseolaris	0.534
Xylocarpus molucensis	0.654

Fig 1. Mean value of wood density for mangrove species (Indrayani et al., 2021)

Reduction of GHG emissions/increase in absorption

Indonesia has established the *Kerangka Metodologi Perhitungan Pengurangan Emisi/Peningkatan Serapan Gas Rumah Kaca Sektor Kehutanan Dan Penggunaan Lahan Lainnya* (Forestry and Other Land Use) through an official document issued by the Ministry of Environment and Forestry in 2023 (KLHK, 2023). This document is a national methodological guideline used to support reporting of mitigation actions in the national registry system (SRN-PPI), while ensuring the integrity of carbon projects in the forestry sector including mangroves, in accordance with the TACCC principles (transparency, accuracy, completeness, consistency over time, and comparability).

The calculation of net emissions can be done using the following formula:

$$PEn = B - En \tag{3}$$

Where:
PEn = Reduction of GHG emissions/increase in absorption for period n (tCO_2e/year)
B = Baseline (tCO_2e/year)
En = Total emissions/absorption in period n (tCO_2e/year)

A buffer rate is needed to overcome the potential risk of displacement/leakage. Therefore, the formula can be adjusted as follows:

$$PEn = B - En - \text{Buffer Deduction} \tag{4}$$

Table 1. Uncertainty Buffer Rate (KLHK, 2023)

Uncertainty of Aggregate Emission Reductions	Uncertainty Buffer Factor
≤ 15%	0%
> 15% and ≤ 30%	4%
>20% and ≤ 60%	8%
>60% and ≤ 100%	12%
>100%	15%

Financial Feasibility Analysis

Financial feasibility analysis is one of the important stages in evaluating an investment project. This analysis is carried out to determine whether a project generates greater financial benefits compared to the costs incurred so that a project can be said to be financially feasible. This study is very important for projects that require large initial investments and have long-term revenue streams, such as carbon-based projects. The method that can be used in analyzing financial feasibility is capital budgeting, in which there is Net Present Value, Internal Rate of Return, and Paybak Period (Gitman & Zutter, 2014).

Conceptual Framework

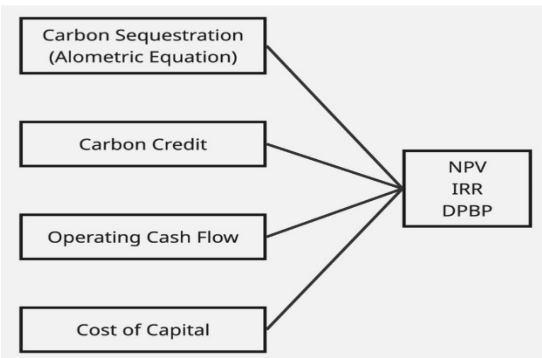

Fig 2. Conceptual Framework

The conceptual framework in Fig 2 describes the research process flow to evaluate the feasibility of a carbon credit-based mangrove restoration project. Initially the *Kerangka Metodologi Perhitungan Pengurangan Emisi/Peningkatan Serapan Gas Rumah Kaca Sektor Kehutanan dan Penggunaan Lahan Lainnya* from KLHK and Allometric Equation are used to find out how much carbon credit potential can be produced and sold as a basis for calculating revenue. After the revenue is known, the operating cash flow can be started to be arranged with other supportive data. Then the cash flow will be discounted with cost of capital to become discounted cash flow. When cash flow and discounted cash flow have been calculated, NPV, IRR, and DPBP can be obtained.

3. Research Method

This study uses a quantitative descrptive method. According to (Rana et al., 2022) Quantitative method is the process of answering research questions through the collection and analysis of numerical data so that it is very suitable for this study which seeks to conduct financial evaluations through measurable indicators such as Net Present Value (NPV) and Weighted Average Cost of Capital (WACC). This study is also descriptive in nature because it seeks to provide a comprehensive picture of the project's financial structure, cost components, revenue sources, and relevant policy contexts.

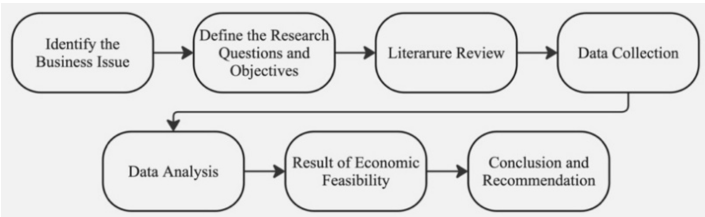

Fig 3. Research Design (Author, 2025)

Structured quantitative procedures were conducted by collecting and using both primary and secondary data. Primary data were obtained through interviews and validation discussions through direct communication and documentation. Secondary data is collected from journals, and internet sources to enrich data analysis. Primary data includes cost estimation, MRV cost, government regulations, and planting plan details. Secondary data includes emission calculation factors and carbon sequestration.

The collected data were analyzed using financial modeling tools in the form of cash flow for 30 years, WACC, NPV, Discounted Payback Period, and IRR via Microsoft Excel. The feasibility of this project was evaluated starting with the preparation of cash flow projections using various assumptions from the dataset. Cash flow is prepared for 30 years based on the maximum duration of the forestry sector mitigation action project in the *Skema Sertifikasi Pengurangan Emisi GRK Indonesia* (KLHK, 2023). Initial investment and operating expenses estimates are based on datasets from Mangrovin. Operating expenses will be adjusted annually with inflation figures from Bank Indonesia to avoid underestimating long-term costs. Revenue figures are obtained based on carbon credits generated from the project and carbon prices. Revenue will then be reduced by operating expenses, depreciation, and tax to determine net operating profit after tax (NOPAT). Depreciation is then added back to NOPAT to determine Operating Cash Flow.

$$\text{Revenue} = \text{Carbon Credits} \times \text{Carbon Price} \quad (5)$$

$$\text{NOPAT} = \text{Revenue} - \text{Expenses} - \text{Depreciation} \quad (6)$$

$$\text{Operating Cash Flow} = \text{NOPAT} + \text{Depreciation} \quad (7)$$

Weighted Average Cost of Capital (WACC) was sought to discount the cash flow projections that had been prepared. WACC is the average rate of return on the cost of capital incurred by a company for financing and must be met to satisfy investors and lenders. WACC is used as a discount rate in assessing a project so that it becomes an important indicator in investment analysis that has a mixed capital structure by considering the risk and cost of capital from various sources of financing (Ross et al., 2002). WACC can be formulated as follows:

$$WACC = E \times re + D \times rd \times (1 - T) \quad (8)$$

Where:
E= proportion of equity
D= proportion of debt
re= cost of equity
rd= cost of debt
T= Tax

Discounted Cash Flow (DCF) is a valuation method to determine the present value of future cash flows by discounting the cash flows. DCF can show how much value is projected to be added by a project (Ross et al., 2002). The following formula can be used to calculate DCF.

$$PVt = Ct / (1+r)t \quad (9)$$

Where:
Ct = operating cash flow year t
r = discount rate (WACC)
t = time or period

From the discounted cash flow, NPV, IRR, and Discounted Payback Period were finally obtained which were assessed to determine whether this project was feasible or not. Net Present Value or NPV is the difference between the market value of an investment and the costs incurred for the investment (Ross et al., 2002). NPV is obtained by finding the difference between the present value of cash inflows and the present value of cash outflows using a certain discount rate. With discounted cash flow we can find NPV by summing all discounted cash inflows for overall period. With undiscounted cash flow, NPV is obtained using the following formula:

$$NPV = [CFt / (1+r)t] - CF0 \quad (10)$$

Where:
CF0 = project's initial investment
CFt = operating cash inflows
r = discount rate
t = time or period

Internal Rate of Return (IRR) can be interpreted as the discount rate that allows the NPV value of an investment project to have a value of zero (Ross et al., 2002). It can be said that IRR is one of the most important alternatives besides NPV to assess the feasibility of a project. Because NPV is zero, IRR can be formulated as follows:

$$0 = [CFt/ (1+IRR)t] – CF0 \quad (II.7)$$

Where:
CF0 = project's initial investment
CFt = cash inflows
t = time or period

Discounted Payback Period is the time required for cummulative discounted cash flow to be equal to the initial investment (Ross et al., 2002). The difference with Payback Period is that DPBP ignores the time value of money. The consideration of decision making using DPBP is that the faster a project returns capital, the more attractive the investment becomes.

$$DPBP = t-1 + [(0-DCFt-1)/(DCFt- DCFt-1)] \quad (II.8)$$

Where:
t = year when cumulative discounted cashflow passed 0
DCF = discounted cash flow

Furthermore, sensitivity analysis was carried out to determine critical variables, understand risks, and as a reference for decision-making. There are five variables that are assumed to have a potential impact on the feasibility of this project, namely carbon prices, initial investment, operating expenses, carbon sequestration, and WACC. Each variable will be evaluated for its impact by changing its value by -20%, -10%, +10%, and +20%.

4. Result and DIscussion

Carbon Sequestration

Table 2. Carbon Sequestration

T	Cummulative ABG & BGB Biomass (kg)	Cummulative Biomass Carbon (ton)	Cummulative Soil Carbon (ton)	Cummulative tCO2e	tCO2e in T
1	6,978,667	3,489	2,861	23,307	23,307
2	15,485,615	7,743	6,349	51,717	28,411
3	28,102,924	14,051	11,522	93,855	42,138
4	45,248,798	22,624	18,552	151,117	57,262
5	67,289,272	33,645	27,589	224,726	73,609
6	94,552,999	47,276	38,767	315,779	91,053
7	127,340,206	63,670	52,209	425,278	109,499
8	165,928,585	82,964	68,031	554,152	128,874
9	210,577,427	105,289	86,337	703,265	149,114
10	261,530,638	130,765	107,228	873,434	170,168
11	319,019,021	159,510	130,798	1,065,428	191,994
12	383,262,053	191,631	157,137	1,279,980	214,552
13	454,469,300	227,235	186,332	1,517,791	237,811
14	532,841,564	266,421	218,465	1,779,531	261,740
15	618,571,826	309,286	253,614	2,065,844	286,313
16	711,846,034	355,923	291,857	2,377,352	311,508
17	812,843,769	406,422	333,266	2,714,654	337,302
18	921,738,815	460,869	377,913	3,078,331	363,677
19	1,038,699,651	519,350	425,867	3,468,945	390,614
20	1,163,889,872	581,945	477,195	3,887,043	418,098
21	1,297,468,566	648,734	531,962	4,333,156	446,113
22	1,439,590,640	719,795	590,232	4,807,801	474,645
23	1,590,407,112	795,204	652,067	5,311,483	503,682
24	1,750,065,368	875,033	717,527	5,844,693	533,211
25	1,918,709,398	959,355	786,671	6,407,914	563,220
26	2,096,480,001	1,048,240	859,557	7,001,614	593,700
27	2,283,514,975	1,141,757	936,241	7,626,255	624,641
28	2,479,949,290	1,239,975	1,016,779	8,282,287	656,032
29	2,685,915,240	1,342,958	1,101,225	8,970,151	687,864
30	2,901,542,586	1,450,771	1,189,632	9,690,282	720,131

Calculation of carbon absorption is done based on aboveground biomass and belowground biomass using allometric equation. The growth of mangrove tree diameter is used as a reference for increasing biomass weight. The biomass weight is then used as a basis for obtaining the value of carbon absorbed which is then converted into carbon using a conversion factor of 0.5 (IPCC, 2006). This means that half of the biomass is carbon. In order to become carbon credit, the carbon is converted by a factor of 3.67 (IPCC, 2006) to determine the amount of CO2 that is equivalent to the amount of carbon contained in the biomass. The results show that this project can absorb CO2e as much as 23,307 tCO2e to 720,131 tCO2e per year. In 30 years, this project has the potential to absorb total emissions of more than 9 million tCO2e.

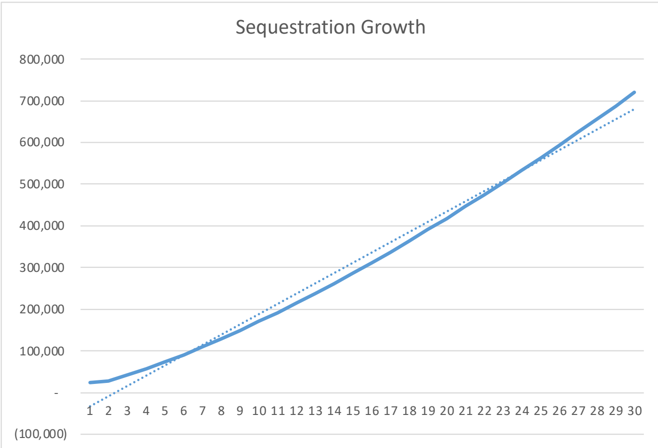

Fig 4. Carbon Sequestration Growth

The CO2 absorption value in the early years is still low, in line with the small diameter. Therefore, along with the increase in tree diameter, biomass also increases non-linearly exponentially, because the exponents in the AGB and BGB formulas are greater than 2.

Total Emission

During the planting phase, the fuel used reached 42.15 m^3, with a gasoline density of 837.5 kg/m^3 and a net calorific value (NCV) of 42.66 TJ/Gg. Based on this data, the total energy consumption is 1.51 terajoules (TJ) (MoEMR, 2018). With an emission factor of 69.04 tons CO_2/TJ based on official data from MoEMR (2023), the total GHG emissions from fuel combustion during this phase are estimated to be 103.97 tons CO_2. For maintenance activities, fuel usage is recorded at 6.74 m^3 per year, so emissions are estimated at 16.63 tons of CO_2 per year. Calculations show that emissions from fertilizers are 0.02 tCO_2e/year. The contribution of emissions from fertilizers is indeed low, but this recording is still important as part of the MRV obligation.

Year 1	120.63	tCO2
Year 2	16.66	tCO2
Year 3-50	16.63	tCO2

Fig 5. Total Emission

Based on Fig 5, GHG emissions from this project are variable because the activities carried out are also different. The first year has the highest emissions because there is a planting process that burns fuel massively. Emissions decrease drastically because the activities that have the potential to produce emissions are only fertilizer and transportation for maintenance. From the third to the 30th year, the activities are only maintenance so that the emissions released are constant at 16.63 tons of CO_2e per year.

Carbon Credit

In accordance with the *Kerangka Metodologi Perhitungan Pengurangan Emisi/Peningkatan Serapan Gas Rumah Kaca Sektor Kehutanan dan Penggunaan Lahan Lainnya* (KLHK, 2023), emission reduction or increased absorption of GHG that can be issued as carbon credit is the result of reducing total emissions from the baseline which is then adjusted again with the buffer. The baseline data for wetlands and mangroves from the *Peta Jalan Perdagangan Karbon Sektor Kehutanan* (KLHK, 2023) is zero from 2000 to 2020, so if forecasted for the future the results are certain to remain zero. Therefore, the baseline in this study is also set at zero. A zero baseline means that without this project the area emits zero emissions.

Table 3. Potential Carbon Credits can be Issued

T	Baseline (B)	Emission		Total Emission/Absorption (En)	Reduced Emission/ Increased Absorption (PEn)	Carbon Credits (After Buffer -15%)	For Upfront Buyer	Saleable Carbon Credits
		Sequestration	Fuel and Fertilizer					
1	0	(23,307)	120.6	(23,186)	23,186	19,708		0
2	0	(28,411)	16.7	(28,394)	28,394	24,135		0
3	0	(42,138)	16.6	(42,121)	42,121	35,803	37,182	42,464
4	0	(57,262)	16.6	(57,245)	57,245	48,659		48,659
5	0	(73,609)	16.6	(73,592)	73,592	62,553		62,553
6	0	(91,053)	16.6	(91,036)	91,036	77,381		77,381
7	0	(109,499)	16.6	(109,483)	109,483	93,060		93,060
8	0	(128,874)	16.6	(128,857)	128,857	109,528		109,528
9	0	(149,114)	16.6	(149,097)	149,097	126,733		126,733
10	0	(170,168)	16.6	(170,152)	170,152	144,629		144,629
11	0	(191,994)	16.6	(191,977)	191,977	163,181		163,181
12	0	(214,552)	16.6	(214,536)	214,536	182,355		182,355
13	0	(237,811)	16.6	(237,794)	237,794	202,125		202,125
14	0	(261,740)	16.6	(261,723)	261,723	222,465		222,465
15	0	(286,313)	16.6	(286,297)	286,297	243,352		243,352
16	0	(311,508)	16.6	(311,491)	311,491	264,768		264,768
17	0	(337,302)	16.6	(337,286)	337,286	286,693		286,693
18	0	(363,677)	16.6	(363,660)	363,660	309,111		309,111
19	0	(390,614)	16.6	(390,597)	390,597	332,008		332,008
20	0	(418,098)	16.6	(418,081)	418,081	355,369		355,369
21	0	(446,113)	16.6	(446,096)	446,096	379,182		379,182
22	0	(474,645)	16.6	(474,628)	474,628	403,434		403,434
23	0	(503,682)	16.6	(503,665)	503,665	428,115		428,115
24	0	(533,211)	16.6	(533,194)	533,194	453,215		453,215
25	0	(563,220)	16.6	(563,204)	563,204	478,723		478,723
26	0	(593,700)	16.6	(593,684)	593,684	504,631		504,631
27	0	(624,641)	16.6	(624,624)	624,624	530,930		530,930
28	0	(656,032)	16.6	(656,015)	656,015	557,613		557,613
29	0	(687,864)	16.6	(687,848)	687,848	584,671		584,671
30	0	(720,131)	16.6	(720,114)	720,114	612,097		612,097
Total	0	(9,690,282)	603		9,689,679	8,236,227	37,182	8,199,045

In the Saleable Carbon Credits column in Table 3 the first and second years are recorded as zero because the issuance process is only carried out in the third year. So in the third year the carbon credits that can be sold are the accumulation of PEn in the first to third years. However, previously some carbon credits must be set aside for buyers who have paid in advance. The buyer contributed funding of 50% of the initial investment which if converted into carbon credits at a price of USD 10, the buyer is entitled to 37,182 carbon credits. Overall, this project can generate 19,708 to 612,097 carbon credits annually and over a 30-year period can generate more than 8 million carbon credits.

Project Parameter Projection
Initial Investment and Operating Expenses

The initial investment for this project consists of four categories, namely planning, plant, and planting. The total initial investment of IDR 12.1 billion shows a fairly large project scale. Investment is predominantly allocated to the plant as the main component in this project. Operational expenses in the first and second years are the largest operational expenses, which is IDR 5.3 billion. This is because fertilizer is still needed to support the growth of newly planted trees. The fertilizer used is quite massive, so it is also needing huge cost. In years other than the first two years, operating expenses are relatively lower, IDR 2.1 billion and IDR 2.2 billion. This is because the costs required are only for maintenance and MRV. In these years, trees no longer require fertilizer.

Project Revenue

The revenue from this project is based on the number of carbon credits successfully registered and the carbon price. The revenue generated varies each year considering that the carbon credits generated also vary each year. With a carbon price of USD 10, the revenue generated per year from this project is IDR 6.9 billion to IDR 99.6 billion and the total revenue in the 30-year project period is more than IDR 1.3 trillion. Revenue continues to increase from year to year because of the increase in sequestration each year. If it is compared with the amount of initial investment and operating expenses, the revenue generated from this project has quite good performance.

Financial Feasibility

Table 4. Feasibility Indicators

Net Present Value	IDR 223,282,582,037	IDR
Payback Period	6.1	years
Disc. Payback Period	7.0	years
Internal Rate of Return	29.18%	per annum
Profitability Index	19.43	times

The results of the feasibility indicators are shown in Table 4. The NPV value of IDR 223 billion implies that this project is not only able to cover its investment costs, but also provides significant added value. The IRR was recorded at 29.18%. This figure is much higher than the Discount Rate (WACC 7.15%). This means that this project produces competitive returns and will attract investors, especially in the context of social and environmental-based investments. Moreover, based on the PI, this project is able to convert every IDR 1 invested into an NPV of IDR 19 so that this project has a fairly high added value. Based on the PBP, this project is able to return the initial investment in 6.1 years. However, if we consider the time value of money in the Discounted Payback Period, the payback period increases to 7 years. For restoration projects that are quite complex and have a high initial investment, this payback period is quite fast. With an NPV far exceeding zero, an IRR greater than the WACC, and a fairly fast DPBP, this project can be declared financially feasible.

Sensitivity Analysis

For sensitivity analysis, the author selected several variables that are believed to affect the financial feasibility of mangrove restoration projects. The variables selected are carbon price, initial investment, operating expenses, sequestered carbon, and WACC.

Table 5. Scenarios Impact to NPV

Impact Percentage to NPV					
Scenario	Price	Investment	Opex	Carbon	WACC
-20%	-24.128%	1.085%	3.107%	-24.475%	30.914%
-10%	-12.064%	0.542%	1.554%	-12.237%	14.296%
10%	12.064%	-0.542%	-1.554%	12.237%	-12.332%
20%	24.128%	-1.085%	-3.107%	24.475%	-23.000%

Table 6. Scenarios Impact to IRR

Impact Percentage to IRR					
Scenario	Price	Investment	Opex	Carbon	WACC
-20%	-12.357%	6.647%	6.051%	-13.362%	0.000%
-10%	-5.994%	3.148%	2.948%	-6.519%	0.000%
10%	5.688%	-2.854%	-2.804%	6.249%	0.000%
20%	11.114%	-5.461%	-5.474%	12.270%	0.000%

Table 7. Scenarios Impact to DPBP

Impact Percentage to DPBP					
Scenario	Price	Investment	Opex	Carbon	WACC
-20%	15.452%	-5.669%	-7.534%	17.352%	-3.074%
-10%	6.766%	-2.820%	-3.830%	7.678%	-1.558%
10%	-5.980%	2.528%	3.559%	-6.790%	1.484%
20%	-10.824%	5.056%	7.250%	-12.286%	3.054%

In Fig 6 WACC shows a large impact on NPV for the -20% scenario, which is 30.9%. The results are somewhat different in the +20% scenario, WACC has an impact of -23% on NPV. WACC is used as a discount rate in calculating the present value of the project's cash flows, so it is natural that this factor has such an impact. Therefore, changes in financing policies, discount rates, or capital structures very affect project feasibility.

Furthermore, the factor that has a large impact on NPV is the revenue factor (the amount of carbon sequestration and the price of carbon). In the ±20% scenario, price has an impact of ±24.1% and ±24.5% for carbon. This makes the WACC and revenue component the main determinant of the financial feasibility of a mangrove restoration project. Small fluctuations in this parameter can significantly change the NPV, so this aspect requires special attention in risk management strategies.

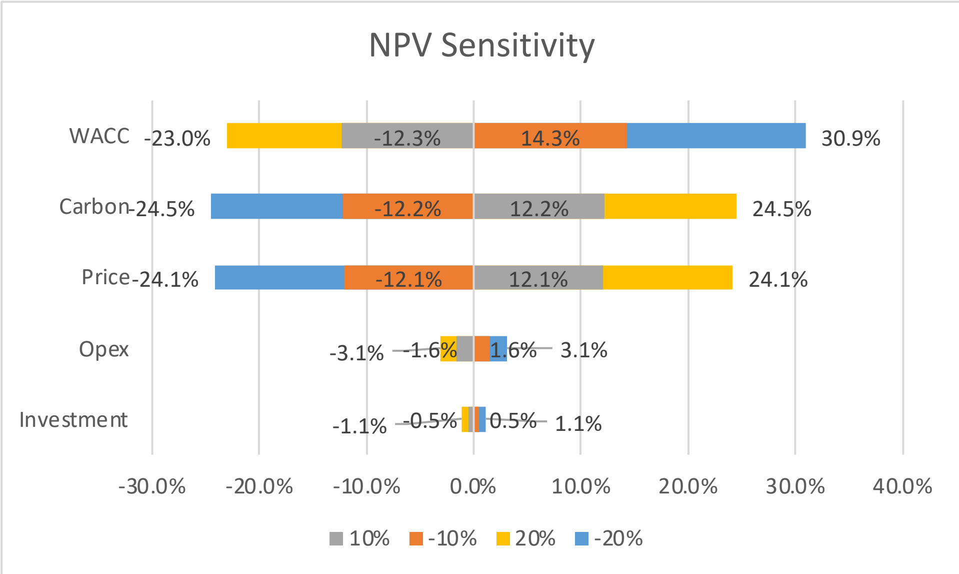

Fig 6. NPV Sensitivity

Operating costs have a not very significant impact on NPV, which is around ±3.1% in the ±20% scenario. Nevertheless, long-term operational efficiency is still very important to maintain project profitability. Meanwhile, the initial investment cost also has a not very significant impact on NPV, which is only ±1.1% in the ±20% scenario. This shows that although the initial investment is quite large in nominal terms, this cost only has an impact at the beginning of the project and is not a major risk factor in the long term.

WACC has a moderate impact on NPV. In the ±20% scenario, the impact of WACC on NPV is ±32.598%. WACC is used as a discount rate in calculating the present value of the project's cash flows, so it is natural that this factor has such an impact. Therefore, although not as large as the influence of price and carbon volume, changes in financing policies, discount rates, or capital structures can affect project feasibility.

Non Financial Co-Benefits

The mangrove ecosystem restoration project in the coastal area not only provides economic benefits for carbon credit issuers. Of course, this project is able to contribute to climate change mitigation through emission avoidance and carbon sequestration. This is evidenced by the calculation of the potential carbon reserves that this project will obtain, which is 6,859,854 tons of CO^2e in a project period of 30 years. However, not only that, mangrove forests are also one of the most valuable ecosystems in the world because they have a multifunctional role in a complex socio-ecological system (Bhowmik et al., 2022).

According to Kathiresan (2012), mangroves protect communities from damage to coastal infrastructure by being a natural barrier to tsunamis, storm surges, cyclones, and floods. Coastal erosion can be prevented by trapping sediment by complex mangrove roots so that the coastline becomes more stable. Infrastructure from mangrove forests is also believed to be more cost-effective than artificial buildings. In his research, Menéndez et al. (2020) state that the impact of waves can be reduced by up to 66% by mangrove ecosystems, thus providing significant protection for coastal communities.

The efficiency of mangroves in trapping and recycling nutrients is very high (Kathiresan, 2012). Mangroves enrich coastal waters and support various organisms with the detritus they produce. This ecosystem is a breeding ground and an important feeding ground to support the survival of various animals. With its ability to provide protection and a nutrient-rich environment, mangrove forests are believed to be able to protect marine ecosystems.

Mangrove forests are a natural habitat for various species of flora and fauna, so the loss of mangrove forests can cause many species of plants and animals to become endangered (Suriadi et al., 2024). Various species of birds, fish, mammals, and even invertebrates, live and thrive relying on the mangrove forest ecosystem. Mangrove forests act as a source of food (feeding ground), a breeding habitat (nursery ground), and a place to lay eggs (spawning ground). Not only animals, but the mangrove forest ecosystem also plays an important role in maintaining various plant species, to various biota associated with mangroves such as bacteria, lichens, fungi, algae, and terrestrial species.

Mangrove forests also play an important role in community food security. The people of Sinjai, South Sulawesi, found a positive correlation between mangrove forests and fish catches, so they took action to protect mangrove forests (Suriadi et al., 2024). In addition, as previously explained, mangrove forests are also a habitat for various other animals that can be a source of food for the surrounding community. Not only that, but mangrove forests are also known to provide honey production (Kathiresan, 2012) and the fruit can also be used to make various types of food (Rosulva et al., 2021).

The mangrove ecosystem area also has the potential to become an attractive ecotourism destination thanks to the combination of beautiful forest views, coral reefs, and beaches which are an added value (Akbar et al., 2021). Educational and ecological aspects are also inseparable aspects of mangrove forest tourism. This ecotourism potential can provide an alternative for the livelihoods of the surrounding community. These benefits are not limited to the mangrove forest area, but also to the surrounding areas. The community can work to maintain ecotourism or can also develop various culinary, lodging, and other businesses. Ecotourism is sustainable tourism, so that the income of the surrounding community can increase while preserving the ecosystem at the same time.

Business Solution

Based on sensitivity analysis, revenue factors such as carbon price and carbon volume have the highest influence, which is around ±24.2% to ±24.6% for the impact to NPV. One way to overcome this problem is to increase carbon sequestration by increasing tree density. Currently, Mangrovin only plans 15,000 seedlings per hectare, while the Manual Restorasi Ekosistem Hutan Mangrove untuk Aksi Mitigasi Indonesia's FOLU Net Sink 2030 explains that planting mangrove seedlings can be done with a distance of 0.5 meters, allowing planting as many as 40,000 seedlings per hectare (KLHK, 2022) . By increasing the number of trees, the volume of carbon absorbed will directly increase, increasing the potential revenue generated from the sale of carbon credits. Mangrovin can also diversify revenue so that it does not depend only on fluctuations in carbon prices in the market. The potential for additional revenue can come from the development of mangrove-based ecotourism and the sale of derivatives of non-timber forest products such as mangrove fruit. With this diversification, Mangrovin can strengthen income stability while increasing the socio-ecological value of the project in the eyes of investors and the community.

WACC is known to have a very significant impact on NPV. To overcome this sensitivity, one strategic solution is to optimize the project financing structure through blended finance—combining equity financing with low-cost funding sources such as grants, green loans, or advance payments from carbon credit buyers (advance purchase agreements). Although the sensitivity to opex is not as large as the revenue factor, it is also worth anticipating. The largest component of opex is the MRV cost, so Mangrovin should verify and issuance applications periodically, not every year. This approach will reduce the frequency of MRV so that it will directly reduce opex.

Furthermore, Mangrovin needs to compile and register DRAM as soon as possible according to SPEI's direction so that the additionality principle can be fulfilled because this is an important requirement in recognizing carbon credits. DRAM is compiled so that the "zero point" can be known with certainty. If the project is carried out before the DRAM is validated, there is a risk that carbon sequestration will not be recognized as an additional emission reduction. This causes the project to not meet the requirements to generate valid carbon credits.

5. Conclusion

This final project examines the financial feasibility of a carbon credit-based mangrove forest restoration project being initiated by Mangrovin. The results of the study indicate that this project is financially feasible because it produces a positive Net Present Value and an Internal Rate of Return that is greater than the discount rate. This project is projected to generate an NPV of IDR 223 billion in 30 years. This project also has the potential to generate an IRR of 29.18%, greater than the discount rate of 7.15%. In addition, for the Discounted Payback Period, this project is projected to return the investment within 7 years if considering the time value of money.

Sensitivity analysis shows that NPV, IRR, and Discounted Payback Period are very sensitive to revenue factors such as carbon volume and carbon price. A change of ±20% to carbon volume has an impact of ±24.5% on NPV, ±12.2%-13.3% on IRR, ±12.3%-17.4% on DPBP. Meanwhile a change of ±20% of carbon price has an impact of ±24.1% on NPV, ±11.1%-12.3% on IRR, and ±10.8%-15.4% on DPBP. Therefore, these two revenue factors are the risks that must be anticipated the most. Anticipation can be done by increasing the volume of carbon absorption by planting more trees and diversifying revenue sources. WACC has the greatest impact on NPV, a change of ±20% of WACC has an impact of ±23%-30.9% on NPV. Therefore, a maximum capital structure is needed so that the cost of capital becomes less expensive. Opex, although it does not have as big an impact as carbon price and volume, must still be a concern. Opex efficiency needs to be carried out, especially on MRV which costs the most in opex.

In addition to the financial aspect, Mangrovin must also pay attention to existing regulations. Projects are required to follow SPEI so that carbon credits can be issued legally. DRAM registration is carried out as soon as possible so that the additionality principle can be fulfilled. In addition, the use of the right methodology can also be an advantage in the validation and verification process. Thus, compliance with regulations is not only an administrative obligation, but also a strategy to obtain legal recognition of carbon credits and open access to climate finance.

Nature-based projects like this project do not only generate financial benefits from carbon sales, but they also have various co-benefits that are ecologically and socially valuable. Therefore, the next highly relevant research direction is the quantification and monetization of these co-benefits. This approach will provide a more holistic picture of the total value of the project, not only in the context of investor profitability, but also in the framework of sustainability and equitable development.

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