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Potential Increase in Local Original Revenue (PAD) of Cilacap Regency from the Carbon Pricing Sector

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Abstrak: Climate change in almost all regions including Indonesia not only has an impact on decreasing environmental quality, but also has an impact on the sustainability of the local economy. This is exacerbated by a decrease in carbon sequestration due to land use change and an increase in carbon emissions from various activities. This study aims to conduct an inventory of sequestration, emissions, and carbon valuation so that information about the potential increase in Regional Original Revenue (PAD) of Cilacap Regency from the carbon pricing sector can be obtained. Land cover data from Rupabumi Indonesia (RBI) was converted into carbon sequestration values according to the sequestration constant. Meanwhile, carbon emission data was obtained from Aksara-Bappenas. The results of the sequestration and emission are used for Net Zero Emission (NZE) evaluation which is then evaluated as a potential increase in PAD from the carbon pricing sector. This study showed the potential for sequestration and carbon emissions in the Cilacap Regency of 7,191,181.44 tons CO2 eq and 4.971.555,00 tons CO2 eq respectively. The sequestration that is greater than emissions shows the NZE achievement with an economic value of USD 4,439,252.88 or has the potential to increase PAD by 23.75% from 2022 gains.

Keywords: Carbon Emissions, Carbon Pricing, Carbon Trade, Local Original Revenue, Net Zero Emissions, Sequestration

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Introduction

The main challenge faced by various regions around the world, including the Cilacap Regency, is global climate change. The primary cause of climate change is greenhouse gas emissions, which predominate by carbon dioxide. Serious impacts on the environment and the sustainability of the local economy include land use change, deforestation, and human activities that contribute to increased greenhouse gas emissions (Fernandes et al., 2021). Changes in land use will contribute 15-20% of total emissions. The estimated annual carbon is almost 1.6 billion tons (For Cities by Cities &; Global Covenant of Mayors for Climate &; Energy, 2019). Therefore, one way to reduce the negative impact of global warming is by preserving existing carbon stores through restoration and conservation. The ability of forests to store carbon will play a major role in reducing carbon emissions (Crumpler &; Bernoux, 2020).

The Indonesian government has affirmed the commitment to reduce national emissions by 29% and 41% by 2030, referring to unconditional and conditional mitigation scenarios, as part of the implementation of the Paris Agreement (Eddy et al., 2021). Climate change caused by carbon emissions is a real example of economic externalities, namely the impact of economic activities on third parties without their involvement. Carbon emissions are a clear example of negative externalities that need to be overcome to avoid harm in society. To control this negative impact, the Indonesian government, through the Ministry of Finance, plans to implement a carbon pricing policy in 2022.

As an effort to control climate change from a policy perspective, Indonesia has planned a Carbon Pricing policy including a Credit Mechanism, Results-Based Climate Finance (RBCF), Internal Carbon Pricing, Emission Trading System (ETS), and Carbon Tax. Carbon tax is the most common carbon pricing implementation found globally (Ardelia, 2023). The carbon tax rate is IDR 30 per kilogram of carbon emissions, by the provisions of Article 13, Paragraph (9) Chapter VI of Law No. 7 of 2021 concerning Harmonization of Tax Regulations (Law 2021). The implementation of this policy is expected to have an impact on carbon-intensive industries, so production management needs to be adjusted so that production activities continue to run efficiently. If adjustments are not made, production costs may increase due to the additional burden of the carbon tax (Muliani et al., 2018).

The effect of carbon pricing implementation in terms of carbon tax to reduce emissions must be started immediately. The experience of Sweden and Finland as success stories of carbon tax implementation in the world. In the end of 2018, Finland's carbon emissions have decreased significantly by 19.49%. Similar information from Sweden which experienced a 27% reduction in carbon emissions (Barus &; Wijaya, 2022).

Mangrove has a great ability to absorb and store carbon in large quantities and for a long time (Rifandi & Abdillah, 2020). Cilacap Regency has one of the largest mangrove forest areas in Java Island that has been designated as a Centre for Mangrove Conservation and Germplasm Studies in Indonesia. The area known as Segara Anakan and reached 6,450 ha in 1903(Muliani et al., 2018). In 1984 this area decreased to 2,906 ha, decreased again to 1,200 ha in 2000, and now only 400 ha. In 1970, the area of forest ecosystems was recorded as 17.000 ha, in 2005, only 6.000-7.000 ha remained (Ardli et al., 2015). Every year, the area of this ecosystem is degraded by 192.96 ha, due to illegal logging (14.23 m/day), land conversion for agriculture (5.4%), fishponds (2.5%), settlements (1.1%), industry (0.4%), and other land uses (1.7%). Such human activity mainly occurred near settlements in Panikel, Bugel, Cibeureum, Karanganyar, Klaces, and Motean (Middle & Suryono, 2006). Changes in mangrove ecosystem will cause a reduction in carbon sequestration. Mangroves in Segara Anakan, Cilacap Regency have the potential to be one of the solutions as sequestration area in Central Java Province. The Cilacap Regency Government shows that one of the SA ecosystem areas that was still in good condition

until the 2000s was in Ujung Alang Village covering an area of ± 3,428 ha (Ardli et al., 2022).

In the Cilacap Regency, carbon sequestration is an important aspect of responding to climate change. Land use change, deforestation, and human activities have increased carbon emissions, causing serious impacts on the environment and the sustainability of local economies. As a proactive response, the implementation of carbon pricing in Cilacap Regency emerged as an innovative strategy to achieve the duality of goals of reducing emissions and increasing carbon sequestration. A carbon tax as one of the carbon pricing mechanism, creates economic incentives that can encourage companies and individuals to shift to sustainable practices, stimulating investment in conservation and reforestation projects (Zegeye et al., 2023).

This study aims to determine the carbon sequestration in Cilacap Regency and evaluate the emissions produced. The results are then converted based on the global carbon sales value to obtain the potential additional Local Original Revenue (PAD). This revenue can be allocated to support sustainability projects and increase nature's capacity. In addition, the implementation of carbon prices can spur innovation in low-carbon technologies, strengthen people's understanding of carbon impacts, and stimulate awareness of the need for conservation. Thus, the carbon pricing in Cilacap Regency is not only a step to overcome emission problem, but also as a catalyst to strengthen regional capacity in managing carbon and supporting environmental sustainability.

The Government of Indonesia's efforts have been carried out by including mangroves in the national GHG inventory under the wetland category as well as in the establishment of Forest Reference Emission Levels (FREL) for REDD+. Mangroves as a potential net sink will be very important in supporting Indonesia's commitment to the FOLU Net Sink and the Government's target to reduce GHG emissions as stated in the Nationally Determined Contributions (NDC) by 2030(NDC, 2022).

Research on carbon sequestration in Indonesia has been carried out by M. I. Mawardi et al. (2023) and Amru et al. (2025) which provides national carbon sequestration data based on land cover. Not only in national level, evaluation of sequestration and emissions has also been carried out in a regional level. Amru et al. (2025) calculate sequestration and emissions for Central Java Province. In another study also by Amru et al. (2024), calculations of emissions and sequestration were also carried out at the regency level of Brebes and Cilacap. Not only mangrove, but another land use with several vegetation also has high sequestration capabilities, including ebony plants (Damanik & Amru, 2022) and teak (Amru et al., 2023).

From the studies above, it can be concluded that ecosystems in Indonesia have the potential to absorb carbon. However, all of these studies only focus on the ecological aspect and do not consider the economic aspect. By including the economic aspect, especially the additional PAD, will encourage collective efforts by the government and the community. Therefore, it is necessary to calculate carbon sequestration, emissions, and valuation to obtained the potential increase in Cilacap Regency's PAD from the carbon pricing sector.

Research Methods

Location and Time of Research

The research was conducted in Cilacap Regency, Central Java Province. Data from aksara-bappenas shows that Java Island is the largest contributor to emissions in Indonesia. Then, Cilacap Regency was chosen as it has the most mangrove ecosystems in Java Island. This research will be conducted in August – November 2023.

Research Tools and Materials

This quantitative descriptive research aims to provide information on the potential increase in PAD of Cilacap Regency from the carbon pricing sector. The 2022 data used are land cover map data from Rupabumi Indonesia (RBI), carbon emission data from Central Java Province from Aksara-Bappenas data, and population data of Central Java Province and Cilacap Regency from the Statistic Central Bureau (BPS).

Data Collection Methods

The land cover map is used to see each ecosystem and then converted to carbon sequestration value. Meanwhile, individual carbon footprint is needed to calculate carbon emissions. Individual carbon footprint of Indonesia was collected from European Comission (2023) and multiplied by the total population in research location.

Data Analysis Methods

Carbon Sequestration Analysis of Cilacap Regency

Land cover map data is multiplied by the carbon sequestration constant to determine the potential for carbon sequestration and storage in an ecosystem. Briefly, it can be formulated with the following equation.

$$Potential\ Carbon\ Sequestration = Land\ Cover\ Area \times Sequestration\ Constant$$

Carbon Emission Analysis in Cilacap Regency

Cilacap Regency's carbon emissions are calculated using the indirect technique. The emissions generated by each individual in Cilacap is assumed by the individual carbon footprint (ICF) value. By multiplying it with population, this data shows the estimated carbon emission in Cilacap Regency. The European Commission stated that Indonesia has an Individual Carbon Footprint (ICF) of 2.5 Tons CO_2 eq/person/year. The total carbon emissions of Cilacap Regency are calculated by the following equation:

$$\Sigma\ Emission = Individual\ Carbon\ Footprint \times \Sigma\ Population$$

Evaluation of Net Zero Carbon Emission Achievement of Cilacap Regency

The emission and sequestration data of each area was then evaluated by the difference between carbon sequestration and carbon emissions. Briefly, it can be formulated with the following equation:

$$Carbon\ Stock = Carbon\ Sequestration - Carbon\ Emission$$

The difference between carbon sequestration and carbon emissions is a carbon stock that can be included in the interregional carbon trading process.

Analysis of the Potential for Additional Local Original Revenue (PAD) of Cilacap Regency from the Carbon pricing Sector

After knowing the difference between sequestration and carbon emissions in Cilacap Regency, the analysis continued by valuating of excess carbon sequestration using selling value of carbon in the international market (World Bank Group, 2021). The valuation of carbon stocks in Cilacap Regency can be calculated by the following equation:

$$Economis\ Carbon\ Valuation = \Sigma\ Carbon\ Stock \times Carbon\ Price$$

Result and Discussion

Sequestration of Cilacap Regency

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With 2,249.28 km2, or 6.48 percent of the total area, Cilacap is the largest regency in Central Java Province. Cilacap is still developing in terms of its economic, social welfare, and regional expansion. Conversely, Cilacap Regency may potentially see a rise in the amount of greenhouse gases released into the atmosphere. The sector that still contributes significantly to greenhouse gas emissions are energy as well as forest and other land use (FOLU). In the meantime, the subsector that is driving up greenhouse gas concentrations continues to be power generating. According to data from the Directorate General of Electricity (2022), the Cilacap Steam Power Plant (PLTU) generated 12,258,604.50 tons CO_2 eq in emissions in 2020.

Table 1. Land Cover of Cilacap Regency

Land Closure	Area (Ha)	Percentage (%)	Carbon Sequestration Constant (tons CO_2 eq)*	Carbon Sequestration and Storage Potential (tons CO_2 eq)
Jungle	11,665.34	4.71%	98.80	1,152,535.59
Mangroves	7,759.44	3.13%	188.30	1,461,102.55
Shrubs	6,639.13	2.68%	30.00	199,173.90
Plantations/Gardens	66,110.94	26.70%	63.00	4,164,989.22
Paddy	74,482.19	30.08%	2.00	148,964.38
Rainfed Rice Fields	6,626.82	2.68%	2.00	13,253.64
Fields/Fields	16,118.16	6.51%	2.50	40,295.40
Meadow	2,716.69	1.10%	4.00	10,866.76
Settlements and Places of Activity	51,080.20	20.63%	0	
Building/Building	94.50	0.04%	0	
Dock	1.19	0.00%	0	
Pond	193.85	0.08%	0	
Sea Sand	175.54	0.07%	0	
Pool	1.63	0.00%	0	
Lake	31.06	0.01%	0	
River	3,929.02	1.59%	0	
Other Non-Cultivated Vegetation	2.09	0.00%	0	
Total	**247,627.77**	**100%**		**7,191,181.44**

Source : (*) (I. Mawardi et al., 2022)

The sequestration capacity varies depending on the type of plant or land cover. The sequestration rate is dependent on type of plant or land cover and the sequestration constant. With a constant value of 98.80 tons CO_2 eq and 63.00 tons CO_2 eq, respectively, forest and plantations have lower carbon sequestration constants than mangrove, which have the highest sequestration constant at 188.30 tons CO_2 eq. Table 1. shows that even though Cilacap Regency is mostly made up of rice fields, only 148,964.38 tons CO_2 eq could be absorbed because of the low carbon sequestration constant (2 tons CO_2 eq). As opposed to mangrove forests, which cover 7,759.44 hectares and may sequestrate up to 1,461,102.55 tons CO_2 eq. Over a surface area of 247,627.77 hectares, the potential carbon sequestration in Cilacap Regency is 7,191,181.44 tons CO_2 eq equal to 22.50% of the total sequestration in Central Java Province.

According to Table 1, with an area of 74,482.19 hectares, or 30.08% of the overall area, paddy constitute the largest area that can be maximized for carbon sequestration. The remaining largest areas are 16,118.16 hectares, 51,080.20 hectares, and 66,110.94

hectares, respectively, for rice fields, plantations, and settlements/places of activity. Land utilization planning is necessary since land use change plays a crucial role in calculating carbon sequestration.

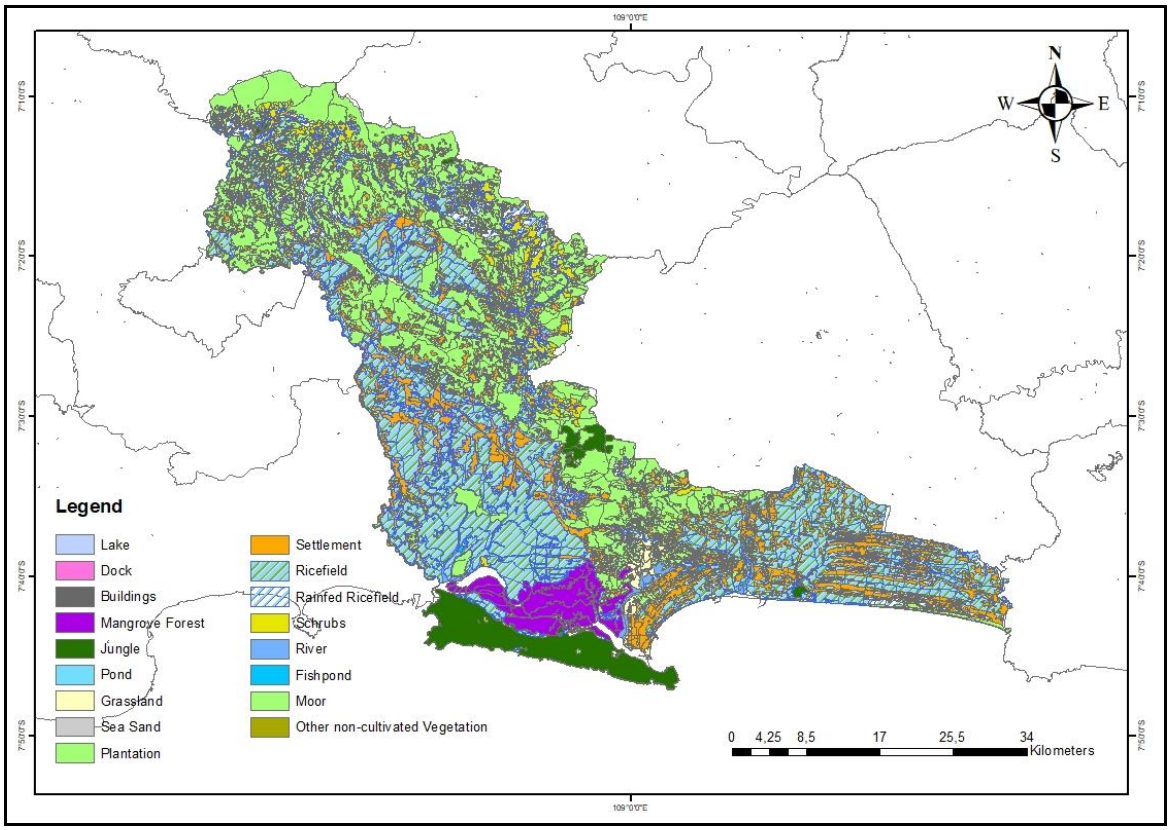

Figure 1. Land cover map of Cilacap Regency

Carbon Emissions of Cilacap Regency

The calculation of carbon emissions of Cilacap Regency is done by multiplying the individual carbon footprint by the total population. Based on the data obtained, the individual carbon footprint of Cilacap is 2.50 tons of CO2eq with a total population of 1,988,622.

Table 2. Carbon Emission Analysis of Cilacap Regency

Variable	Value
Total Population of Cilacap (people)*	1.988.622
Individual Carbon Footprint (tons CO_2 eq)	2,5
Total Cilacap Carbon Emissions (tons CO_2 eq)	4.971.555,0

Source : (*) Statistics Central Bureau of Central Java Province 2022

The Statistics Central Bureau reports that 1,988,622 people live in Cilacap Regency and produced a minimum of 4.971.555,0 tons CO_2 eq annually. This is because, in comparison to other Central Java cities and regencies, Cilacap Regency has a significantly larger population that moves there. Human activities, such as electricity plants, transportation, food supply factories, paper, entertainment, and garbage creation to suit human requirements, all contribute to the high overall carbon emissions in Cilacap Regency.

Evaluation of Net Zero Emission Carbon Achievement in Cilacap Regency

Evaluation of Net Zero Emission achievement is obtained by comparing the potential of carbon sequestration with carbon emissions produced. Similar things have been done by M. I. Mawardi et al. (2023) which evaluates the achievement of Net Zero Emission at the national level with the result that 11.76% of provinces in Indonesia have not achieved Net Zero Emission, while 88.24% or 30 other provinces have achieved Net Zero Emission including Central Java Province. Although the results of the provincial evaluation have shown the position of Net Zero Emission, more detailed studies still need to be carried out.

The difference in sequestration potential and carbon emissions in Cilacap Regency is quite large compared to other cities/regencies in Central Java Province. Based on the calculation results in this study, Cilacap Regency is one of the regions in Central Java Province that has achieved Net Zero Emission according to Table 3 with a difference between sequestration potential and carbon emissions of 2.219.626,44 tons CO_2 eq. Theoretically, this difference in carbon sequestration potential and high carbon emissions can be used to cover the achievement shortfall for other regions through a cluster approach.

Table 3. Analysis of Net Zero Emission Achievement of Central Java Province

Variable	Value
Carbon Sequestration Potential (tons CO_2 eq)*	7.191.181,44
Total Carbon Emissions (tons CO_2 eq)**	4.971.555,00
Advantages of Carbon Sequestration (tons CO_2 eq)	2.219.626,44

Source : (*) National Development Planning Agencies 2022, (**) Statistics Central Bureau of Central Java Province 2022

The main strategy that can be done to achieve NZE is to increase carbon sequestration and reduce carbon emissions produced. Increasing carbon sequestration can be done through the utilization of various vegetation that has high carbon sequestration capabilities. The use of vegetation or plants is a solution in increasing carbon sequestration through increasing the ability of vegetation to absorb carbon through the process of photosynthesis (Mashoreng et al., 2019).

Increasing carbon sequestration also needs to be accompanied by area maintenance. One way of maintaining forests, especially mangroves, can be done through their sustainable use as ecotourism areas. This is similar to the use of the Mangrovesari ecotourism area in Brebes Regency, and the Mangrove Edupark in Karangsong, Indramayu Regency which combines tourist areas as well as mangrove conservation (Anjani et al., 2023; Saraswati et al., 2023). The use of mangrove forests as ecotourism areas not only provides ecological benefits as carbon sinks but also provides economic benefits (Asmin, 2018) which also plays a role in efforts to increase PAD.

In addition, reducing carbon emissions from anthropogenic activities, industries and transportations need to be done by communities in Central Java, especially Cilacap Regency. There are many things that communities can do to reduce carbon emissions especially by using public transportation. This is in line with Dewanto et al. (2020) research, which states that the largest carbon emission burden in Bandung City in 2019 was obtained in the transportation sector with private cars as the largest emission contributor.

Analysis of the Potential for Additional Local Original Revenue (PAD) of Cilacap Regency from the Carbon pricing Sector

Analysis of the potential economic value in this research is valued using the carbon selling value approach in the international market. World Bank Group (2021) estimates that the economic valuation of carbon stocks on the world market reaches USD 50 – 100 per tons by 2030, but the average value of economic valuations of carbon stocks

worldwide is currently at USD 2 per tons. Based on the value of carbon sequestration potential and also the total carbon emissions in this study, the estimated valuation can be seen in Table 4.

Table 4. Valuation of Cilacap Carbon Sequestration Value

Variable	Value
Difference between Sequestration Potential and Carbon Emissions (tons CO_2 eq)	2.219.626,44
World Carbon Price (USD per tons)*	$2
Cilacap Carbon Sequestration Valuation (USD)	USD 4.439.252,88

**Source: World Bank Group (2021)*

Based on table 4 above, it can be seen that the potential income may reach USD 4.439.252,88. This value can still be increased based on the prediction of the world bank which estimates that the carbon selling price will continue to increase until 2030. This result is an opportunity for the Cilacap Regency Government to increase regional revenue.

According to the audited 2022 Cilacap Regency Local Government Financial Statements, Cilacap Regency's revenue is IDR 3,293,132,343.02. PAD revenue amounted to IDR 700,428,762,449.02 consisting of Regional Tax of IDR 280,277,331,102.00 or 40.02%, Regional Retribution of IDR 19,813,134,112.00 or 2.83%, Results of Segregated Regional Wealth Management of IDR 57,360,003,796.00 or 8.19% and Other Legal Local Original Revenue of IDR 342,978,293,439.02 or 48.97%. The 2022 Cilacap Regency PAD component of the tax sector can be seen through Table 6.

Table 5. Realization of PAD (*audited*) Cilacap Regency in 2022

Local Tax Revenue	Value
Hotel	6,090,654,066.00
Restaurant	6,606,133,536.00
Entertainment	1,244,100,499.00
Advertisement	2,575,113,148.00
Street lighting	95,349,526,385.00
Parking	741,803,650.00
Groundwater tax	1,336,029,441.00
Swallow's nest	3,654,400.00
Nonmetallic minerals and rocks	26,244,989,755.00
UN rural and urban affairs	111,681,957,116.00
BPHTB	28,403,369,106.00
Total	280,277,331,102.00

**Source: Financial Report of the Regional Government of Cilacap Regency for Fiscal Year 2022 (Audited), BPPKAD Cilacap Regency (Local Government of Cilacap Regency, 2022)*

The types of regional taxes according to Table 5 are regulated through Law No. 1 of 2022 concerning Financial Relations Between the Central and Regional Governments, where the district/city Government has the authority to collect and manage these sectors for the benefit of regional development. Local revenue through carbon pricing is one of the significant alternative sources of revenue for local governments. A carbon pricing is an economic instrument applied to reduce greenhouse gas emissions by imposing costs on activities or products that produce these emissions. However, there are some records where there are no operational rules that allow regions to collect carbon prices. In Law No. 7 of 2021 regarding HPP, there is explicitly no clause regulating regional authority and implicitly it appears that its authority is in the realm of the central government. To maximize the implementation potential and revenue from the carbon pricing sector, operational rules (Government Regulations or the like) regarding carbon pricing are needed. Based on the results, the differences between carbon sequestration and emissions up to 2.219.626,44 tons CO_2 eq with an economic valuation of USD 4.439.252,88 equal to

IDR 66 billion. Based on this value, the carbon pricing sector has the potential to increase 23.75% of PAD compared to the 2022 gain.

Cilacap Regency is not the only region in Indonesia that has great potential for generating carbon pricing. For this reason, before the regulation is enforced nationally, it is necessary to explain comprehensively the extent of the authority of the Central Government and Regional Governments, including the percentage of revenue sharing. This is important so that local governments can succeed in carbon pricing policies and have the motivation to provide regulations and its implementation at the local level regulation (Peraturan Kepala Daerah/Perkada and Peraturan Daerah/Perda).

Conclusion

Based on the calculations in this study, Cilacap Regency has the potential to increase its Regional Original Revenue (PAD) from carbon pricing initiatives by **23.75%** compared to the **2022 revenue**. This value is derived from the difference between sequestration potential and emissions, which amounts to **2,219,626.44 tons of CO_2 equivalent**, or approximately **USD 4,439,252.88**. The large potential increase in PAD from the carbon pricing sector is expected to drive the implementation of carbon trading in Indonesia through collective efforts between the government and the community. These collective efforts aim to enhance carbon sequestration and minimize carbon emissions, thereby accelerating the achievement of the NDC targets in an economically sustainable manner. Future research can focus on the social approach by analyzing the readiness of the community and policymakers in implementing the carbon market.

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