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Potential Carbon Stocks in the Kasepuhan Karang Customary Area

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Abstract: Customary areas in Indonesia, including Kasepuhan Karang, play a crucial role in forest conservation and climate change mitigation. According to data from the Indigenous Territory Registration Agency (BRWA), the Kasepuhan Karang customary area covers 1.081 hectares, with land cover composition including primary dry forest, settlements, mixed dry agriculture, and rice fields. The methods used in this study include GIS analysis and remote sensing with high-resolution imagery from PlanetScope, as well as field data verification. This study aims to analyze the potential above-ground carbon stocks in the customary area of Kasepuhan Karang, Banten Province. The results show that the primary dry forest land cover has the highest biomass potential of 38.507 Mg and carbon stocks of 18.099 Mg C. The total carbon stocks in the Kasepuhan Karang customary area are 42.986 Mg C, with varying distribution across different land cover classes. Mixed dry agriculture, which dominates this area, also has significant biomass potential and carbon stocks. These findings emphasize the importance of sustainable land management to optimize carbon sequestration potential and support climate change mitigation.

Keywords: Biomass; Carbon; Climate change; Customary area; Indigenous communities; Kasepuhan karang

Introduction

Customary territories in Indonesia are generally located in forest areas. The continuity of forest resources must be monitored through clarity of rights and access control, which are greatly influenced by short-term and long-term goals. The Customary Territory Registration Agency (BRWA) has recorded significant progress in registering customary territories. To date, 1.336 maps of customary territories have been registered with a total area of 26.9 million hectares. These maps are spread across 32 provinces and 155 districts/cities. Of the 1.336 registered customary territories, 219 have received recognition from the local government. This recognition covers an area of 3.73 million hectares, or around 13.9% of the total customary territories registered. Despite progress, there are still 23.17 million hectares of customary territories that have not been recognized by the local government. This shows that there is still a lot of homework to be done in efforts to protect and recognize the rights of indigenous peoples in Indonesia. Based on an analysis of forest cover in 1.336 customary areas, BRWA found that in customary areas there are around 12.9 hectares of prime forest and around 5.37 million hectares of secondary forest.

Kasepuhan Karang is located in Lebak, Banten, and has a customary area of 1.081 ha with a customary forest of 486 hectares. Of this area, 462 hectares are in the Mount Halimun Salak National Park, while the other 24 hectares are areas for other uses. The Kasepuhan Karang indigenous community is led by a customary chief called kokolot or abah. From generation to generation there are customary institutions that regulate customary social norms and customary rituals. There are customary laws

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that regulate the control of natural resources and their utilization areas. This is not written down, but is disseminated verbally; these rules are obeyed by the community so as not to suffer disaster for any violation. Land management in customary forests is still largely dependent on the inherited generation (Amalia, 2019). According to Surati (2021), the Kasepuhan Karang indigenous community depends on the forest as a source of life, medicine, and handicraft materials. Forests are also a place for carrying out traditional rituals, food sources, and water sources that are maintained and passed down from generation to generation. The Kasepuhan Karang indigenous community has local wisdom in dividing the area into several parts, namely: leuweung titipan, leuweung tutupan, and leuweung garapan. Leuweung titipan is a forbidden forest that cannot be entered and is usually close to a spring. Leuweung tutupan is a forest that can be utilized with the permission of the traditional leader and generally contains types of woody plants. Leuweung garapan is a forest managed by the community in the form of rice fields, gardens and fields. In managing the area, there are customary rules that must be obeyed so that the forest remains sustainable (Hidayat et al., 2020). The division of areas in the customary area is one of the spatial planning carried out by indigenous peoples. Planning in spatial planning is an important contribution to the sustainability and social dimensions (Chang et al., 2021).

The aim of this study is to analyze the potential for above-ground carbon stocks in the Kasepuhan Karang customary area, Banten Province.

Method

Research Location

The research was conducted in Kasepuhan Karang which is administratively located in Lebak Regency, Banten Province (Figure 1). This research was conducted from March to May 2024.

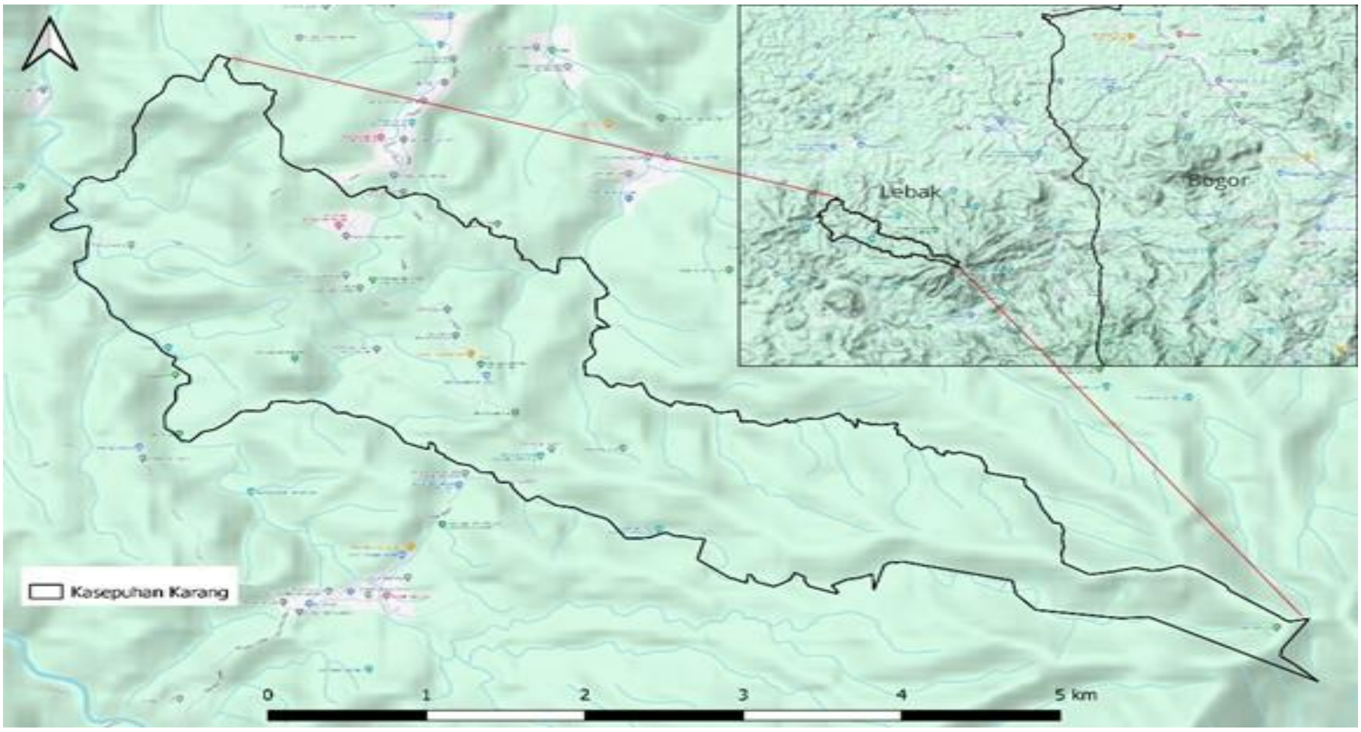

Figure 1. Research location in Kasepuhan Karang, Banten Province

Research Procedures

This research uses GIS and Remote Sensing methods using High Resolution Imagery from PlanetScope which is then verified by checking field data (Ground Truthing). The satellite imagery data used in this study is the PlanetScope Surface Reflectance Mosaics satellite imagery with an acquisition time of 2023. The PlanetScope Surface Reflectance Mosaics satellite imagery has a spectral resolution in the form of Red, Green, Blue and Near-Infrared channels. The PlanetScope imagery has a resolution of 4.77 m per pixel which is included in the High Resolution Imagery (CRT) category. Field data checking (ground truthing) is carried out to verify the PlanetScope satellite imagery data analysis data. Field checking activities to ensure the suitability of the type of land cover resulting from satellite imagery analysis with actual conditions in the field.

Data Analysis

Identification and analysis of land cover and its area using spatial analysis and remote sensing. The satellite imagery that will be used in this study is PlanetScope satellite imagery. Land cover identification is based on the results of land cover ground checks in the field. The ground check results will later be used as samples for land cover classification. Land cover classification using Qgis software using segmentation and supervised classification with the maximum likelihood method. The area of each land cover is analyzed using the calculate geometry tool on the results of land cover classification.

The biomass value for each type of land cover used is sourced from KLHK data in 2022. To estimate the amount of carbon (C) in each type of forest, information on the carbon fraction is needed. The carbon fraction of biomass (dry weight) is assumed to be 47% (1 ton of biomass = 0.47 ton of C) following the 2006 IPCC Guidelines. The conversion of C stock to carbon dioxide equivalent (CO2e) is then obtained by multiplying the C stock by a factor of 3.67 (44/12) (Rypdal et al., 2006). Biomass data uses KLHK data in the FREL document as seen in Tables 1 and 2.

Table 1. Biomass Data in Forest

Forest Type	Island	AGB (Mg ha^{-1})		BGB (Mg ha^{-1})		Forest Ecosystem (Mg ha^{-1})		U (%)
		Mean	SE	Mean	SE	Mean	SE	
Primary dryland forest	Bali Nusa Tenggara	280.45	11.69	81.33	3.39	361.78	12.17	6.6
	Java	347.88	51.35	100.89	17.29	448.77	54.19	23.7
	Kalimantan	325.90	10.05	94.51	2.89	420.41	10.45	4.9
	Maluku	237.85	19.01	68.98	5.88	306.83	19.90	12.7
	Papua	268.57	9.12	77.88	2.63	346.45	9.49	5.4
	Sulawesi	248.28	7.44	72.00	2.14	320.28	7.74	4.7
	Sumatra	340.72	10.17	98.81	2.93	439.53	10.59	4.7
	Indonesia (Average)	291.24	4.35	84.46	1.25	375.70	4.52	2.4
Secondary dryland forest	Bali Nusa Tenggara	138.73	7.09	40.23	2.11	178.96	7.40	8.1
	Java	209.78	13.26	60.84	3.97	270.61	13.84	10.0
	Kalimantan	222.91	4.48	64.64	1.32	287.55	4.67	3.2
	Maluku	168.82	8.43	48.96	2.52	217.78	8.80	7.9
	Papua	224.77	10.99	65.18	3.27	289.95	11.47	7.8
	Sulawesi	166.12	5.46	48.17	1.62	214.29	5.69	5.2
	Sumatra	221.45	6.20	64.22	1.84	285.67	6.47	4.4
	Indonesia (Average)	204.10	2.72	59.19	0.80	263.29	2.84	2.1
Primary swamp forest	Bali Nusa Tenggara*	248.80	12.92	54.74	3.20	303.53	13.31	8.6
	Java*	248.80	12.92	54.74	3.20	303.53	13.31	8.6
	Kalimantan	285.09	24.16	62.72	7.10	347.81	25.18	14.2
	Maluku*	248.80	12.92	54.74	3.20	303.53	13.31	8.6
	Papua	222.87	14.04	49.03	3.49	271.90	14.46	10.4
	Sulawesi*	248.80	12.92	54.74	3.20	303.53	13.31	8.6
	Sumatra	355.63	36.23	78.24	9.68	433.87	37.50	16.9
	Indonesia (Average)	248.80	12.92	54.74	3.20	303.53	13.31	8.6
Secondary swamp forest	Bali Nusa Tenggara*	204.61	4.98	45.01	1.23	249.62	5.13	4.0
	Java*	204.61	4.98	45.01	1.23	249.62	5.13	4.0
	Kalimantan	215.71	7.38	47.46	1.83	263.17	7.60	5.7
	Maluku*	204.61	4.98	45.01	1.23	249.62	5.13	4.0
	Papua	139.88	13.90	30.77	3.55	170.65	14.35	16.5
	Sulawesi*	204.61	4.98	45.01	1.23	249.62	5.13	4.0
	Sumatra	207.06	7.36	45.55	1.83	252.61	7.58	5.9
	Indonesia (Average)	204.61	4.98	45.01	1.23	249.62	5.13	4.0
Primary mangrove forest	Bali Nusa Tenggara*	236.17	15.26	73.45	4.66	309.62	15.96	10.1
	Java*	236.17	15.26	73.45	4.66	309.62	15.96	10.1
	Kalimantan	247.98	14.39	77.12	4.43	325.10	15.05	9.1
	Maluku*	236.17	15.26	73.45	4.66	309.62	15.96	10.1
	Papua	240.64	28.00	74.84	8.57	315.48	29.28	18.2
	Sulawesi*	236.17	15.26	73.45	4.66	309.62	15.96	10.1
	Sumatra*	236.17	15.26	73.45	4.66	309.62	15.96	10.1

Table 2. Biomass Data in Non Forest

Non Forest Type	AGB (Mg ha^{-1})		BGB (Mg ha^{-1})		Total Ecosystem1) (Mg ha^{-1})		U2) (%)
	Mean	SE	Mean	SE	Mean	SE	
Plantation forest	75.78	7.52	24.63	2.44	100.40	7.91	15.44
Shrub	60.39	7.22	14.25	1.70	74.64	7.42	19.48
Plantation	48.10	6.90	15.63	2.24	63.74	7.25	22.30
Settlement	2.17	1.17	0.63	0.34	2.80	1.21	85.18
Open land	2.40	1.36	0.57	0.32	2.97	1.39	92.17
Savana	4.06	1.94	0.96	0.46	5.02	2.00	77.88
Water body	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Swamp shrub	19.34	3.97	4.56	0.94	23.91	4.08	33.42
Dry land agriculture	14.08	7.70	2.82	1.54	16.89	7.85	91.10
Mixed dry land agriculture	64.64	2.30	12.93	0.46	77.56	2.35	5.93
Ricefield	10.00	3.88	2.36	0.92	12.36	3.99	63.27
Pond	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Airport/port	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transmigration area	14.08	7.70	2.82	1.54	16.89	7.85	91.10
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Swamp	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Result and Discussion

Land Cover

The results of satellite image analysis show that there are 4 types of land cover in the Kasepuhan Karang customary area, namely: built-up land (settlements), rice fields/agriculture, mixed dryland agriculture, and primary dryland forest. The rice field/agriculture cover class is an area planted by indigenous people with rice (*Oryza sativa*), and other crops such as cassava, corn, taro, lemongrass, galangal, long beans, cucumbers, pumpkins, chilies, and vegetables to meet daily needs. The primary dryland agricultural cover class is an area containing trees with types of African wood, jeunjing, kadu or durian, mangosteen, petai, jengkol, rubber, coffee, langsat, meranti, mahogany, sengon, rambutan and bananas (Hidayat et al., 2020).

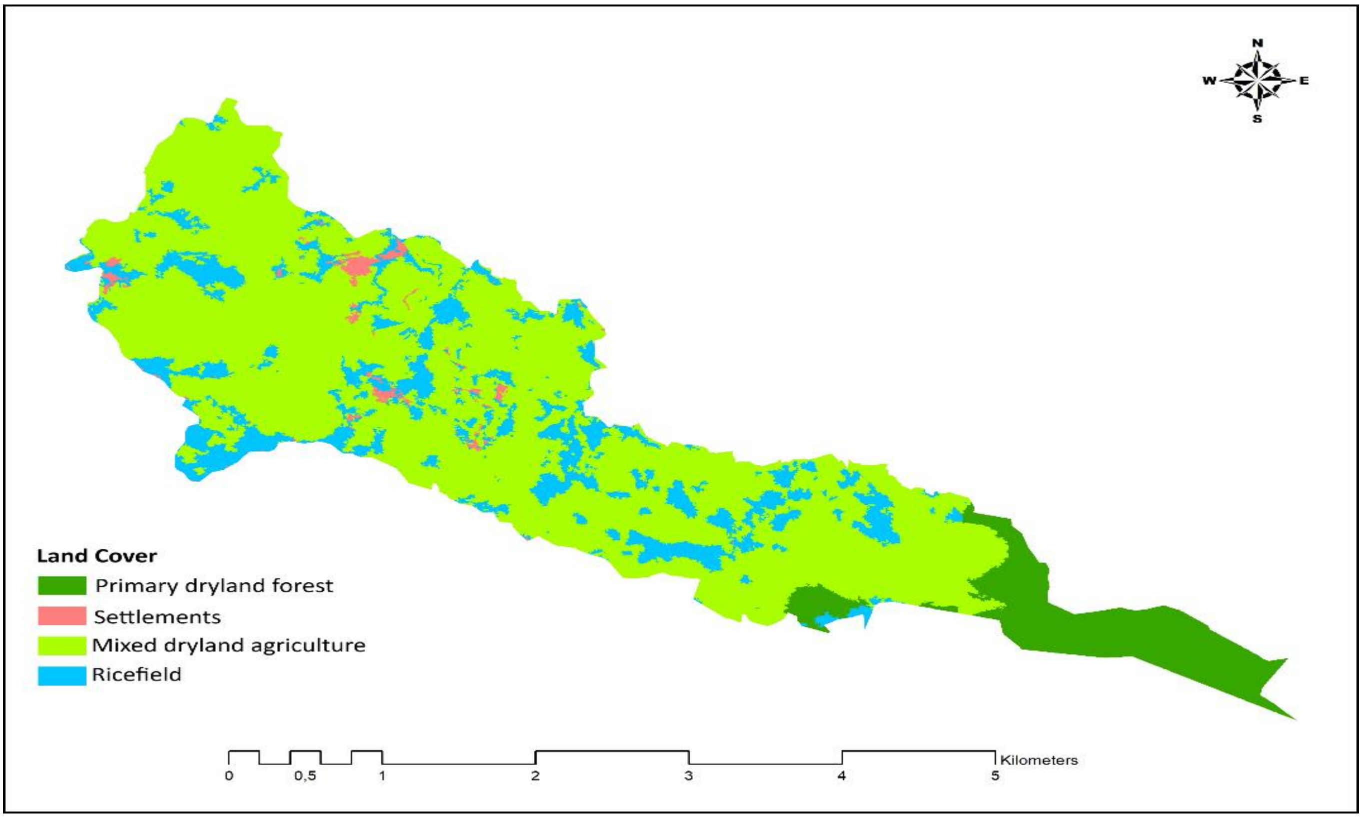

Figure 2. Land cover map in Kasepuhan Karang

The Kasepuhan Karang customary area covers a total land area of 1081 hectares, which is divided into four land cover classes with different compositions and proportions. Of the total land, primary dryland forest covers an area of 111 hectares, which is 10% of the total land. Settlements occupy an area of 13 hectares, only about 1% of the total land, indicating a relatively low building density in this area.

Mixed dryland farming is the dominant category, with an area of 788 hectares, covering 73% of the total land area. This indicates that plantation activities, both for subsistence and commercial purposes, are the main activities in this area. Finally, rice fields, which are wetlands specifically for rice cultivation, occupy 169 hectares or 16% of the total area.

The large proportion of mixed dryland and paddy farming indicates a tendency for land use for intensive plantation activities, which are very important for meeting the food and economic needs of the Kasepuhan Karang indigenous community. Meanwhile, the relatively small forest area emphasizes the challenges that exist in efforts to preserve natural resources and ecological sustainability in the region.

Table 3. Land closure in 2023 in Kasepuhan Karang

Land cover class	Large (ha)	Proportion (%)
Primary dryland forest	111	10
Settlements	13	1
Mixed dryland agriculture	788	73
Ricefields	169	16
Total	1081	100

Biomass Potential

The Kasepuhan Karang customary area has significant biomass potential with a cumulative total of 91.459 megagrams (Mg). Of this amount, the distribution of biomass potential differs significantly between land cover classes, illustrating variations in vegetation and land use in the area.

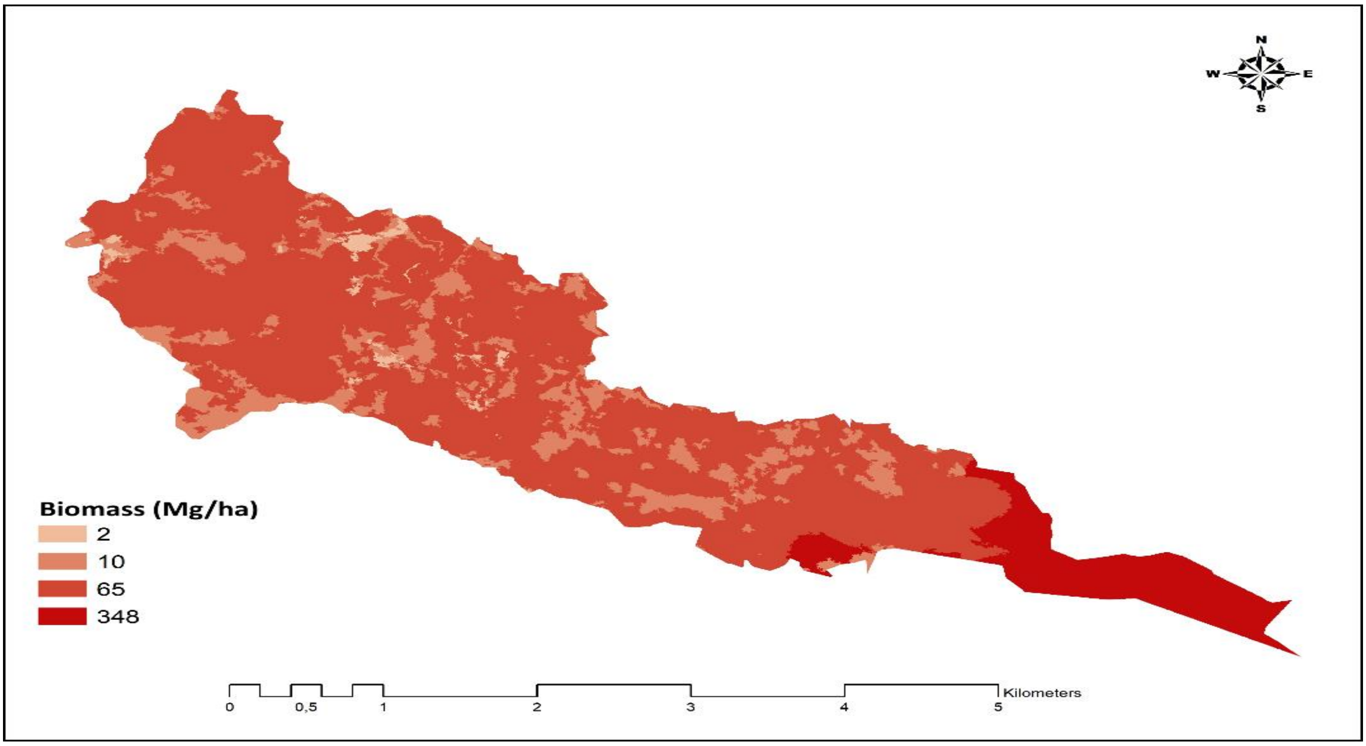

Figure 3. Map of biomass potential in Kasepuhan Karang

Primary dryland forest, covering 111 hectares, has the highest biomass potential among all classes with a total of 38.507 Mg. This reflects the high density and richness of biomass in primary forests, which are important ecosystems in carbon storage and providing other environmental services.

Meanwhile, the settlement, which only occupies 13 hectares, has a very low biomass potential of 28 Mg. This is reasonable considering that residential areas generally have limited vegetation, consisting of small parks and street trees that do not contribute significantly to the total biomass.

Mixed dryland farming, with an area of 788 hectares, has a very large biomass potential, reaching 51.236 Mg. This shows that this agricultural land is planted with multispecies of fruit plants that have high biomass values.

On the other hand, rice fields covering 169 hectares have a biomass potential of 1.687 Mg. Although lower than dryland farming, rice fields still make a significant contribution, especially through the rice plants that grow there.

The high biomass potential in forests and agriculture shows that these two types of land are crucial components in natural resource management strategies and climate change mitigation in the Kasepuhan Karang area, through carbon sequencing and oxygen production.

Table 4. Biomass Potential in Each Land Cover

Land cover class	Biomass potential (Mg)
Primary dryland forest	38.507
Settlements	28
Mixed dryland agriculture	51.236
Ricefields	1.687
Total	91.459

The relevance of aboveground forest biomass as a key indicator of forest carbon storage and sequestration, emphasizes its role in estimating potential emissions resulting from land cover changes such as deforestation or afforestation, which further supports the importance of assessing biomass potential in different land cover types (Herold et al., 2019; Jakovac et al., 2021; Knápek et al., 2020; Meena et al., 2021). The significant biomass potential identified in forest land cover in the Kasepuhan Karang area is in line with the broader context that forest biomass is an important component in carbon sequestration efforts and climate change mitigation strategies (Dumitraşcu et al., 2020).

The benefits of remote sensing data in predicting carbon storage in forests, emphasize the importance of accurate land cover classification for ecosystem management decision making (Potter et al., 2008). This is in line with the approach taken in assessing biomass potential in the Kasepuhan Karang customary area, where spatial analysis is likely to involve remote sensing techniques to map biomass distribution across different land cover types (Du et al., 2014; Potter et al., 2008). Remote sensing technology has proven to be a valuable tool for assessing forest structure and biomass, allowing detailed analysis of carbon stocks across ecosystems (Koppad et al., 2020; Potter et al., 2008).

The importance of managing abandoned land such as shrubs, grasslands, and shrubs through reforestation or planting forest vegetation to maintain soil carbon balance, which shows the importance of land management practices in maintaining carbon stocks (Sufardi et al., 2022). This perspective is in line with findings in the Kasepuhan Karang area, where different land cover types show different biomass potentials, thus underlining the importance of sustainable land management strategies to optimize carbon sequestration potential (Du et al., 2014; Sufardi et al., 2022).

Carbon Stock Potential

The Kasepuhan Karang customary area has a total carbon stock of 42,986 megagrams of carbon (Mg C), which is unevenly distributed among various land cover classes. This distribution shows the important role of various ecosystems in carbon storage, which is essential in climate change mitigation efforts.

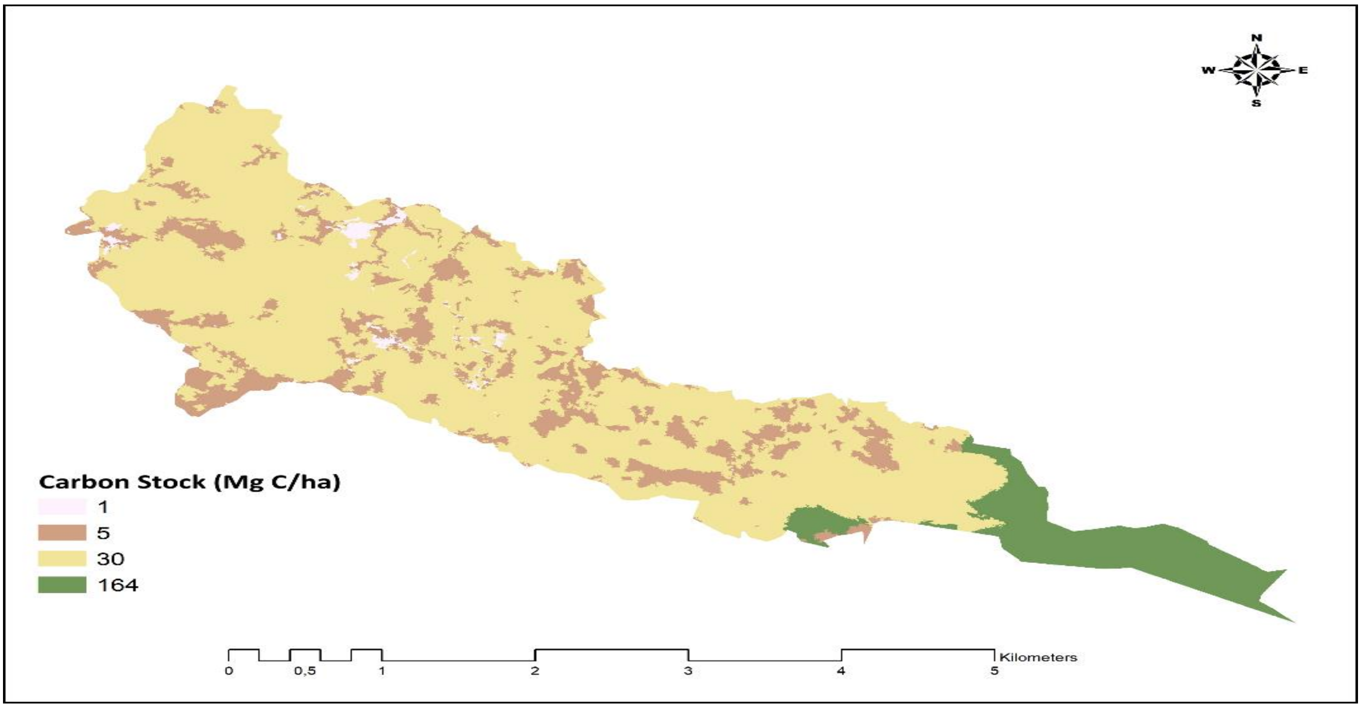

Figure 4. Map of potential carbon stock in Kasepuhan Karang

Primary dryland forest has the highest carbon stock of 18.099 Mg C, indicating its very significant role in storing carbon. Primary forests, with mature vegetation and stable ecosystems, naturally have a greater capacity to store carbon compared to other ecosystems. Its area of 111 hectares with large trees and high biomass greatly contributes to this amount.

In the residential area, which is only 13 hectares in size, the carbon stock is very low, only 13 Mg C. This reflects minimal vegetation and the dominance of artificial structures that are not effective in storing carbon. Mixed dryland farming, which dominates land use with 788 hectares, stores as much as 24.081 Mg C. This indicates that the agricultural practices carried out may involve vegetation or plants that are quite effective in absorbing and storing carbon.

Rice fields, although only covering 169 hectares, also contribute to carbon stocks with a total of 793 Mg C. This indicates that rice fields, with rice plants and other supporting vegetation, also play a role in the carbon cycle in the area. Overall, these carbon stock data emphasize the importance of managing various ecosystem types in Kasepuhan Karang, not only for the sustainability of food production but also for ecological functions such as carbon storage, which are vital in mitigating the impacts of climate change.

Table 5. Potential carbon stocks in 2023 in Kasepuhan Karang

Land cover class	Potential carbon stocks (MgC)
Primary dryland forest	18.099
Settlements	13
Mixed dryland agriculture	24.081
Ricefields	793
Total	42.986

The importance of these findings extends beyond quantification, but explores broader implications for carbon sequestration, climate change mitigation, and the preservation of indigenous territories. Indigenous Peoples play a critical role in the success of nature-based solutions to climate change, as many of the high-carbon forests and peatlands prioritized for such solutions are located within indigenous territories (Carroll et al., 2021; Hiller et al., 2023; Strack et al., 2022; Seddon et al., 2021). This underscores the importance of recognizing and engaging indigenous peoples in environmental conservation efforts, given their close ties to and stewardship of their lands (Thapa et al., 2020; Paolo, 2023).

Conclusion

The Kasepuhan Karang customary area, comprising 1081 ha divided into primary dryland forest (10%), settlements (1%), mixed dryland agriculture (73%), and rice fields (16 %), exhibits both high biomass (91.459 Mg) and substantial carbon stocks (42.986 Mg C), with primary forest and mixed agriculture contributing the lion's share of ecosystem services. The dominance of mixed dryland farming underscores the community's reliance on multispecies plantations for food security and livelihoods, while the relatively limited forest area highlights the need for strengthened conservation measures. Remote-sensing-based land-cover mapping has proven vital in quantifying spatial variations in biomass and carbon potential, reinforcing its role in evidence-based resource management. These findings point to two complementary strategies: (1) sustain and enhance agroforestry practices that combine high-biomass species, and (2) expand forest restoration on underutilized lands to bolster carbon sequestration and ecological resilience. Engaging the indigenous custodians of Kasepuhan Karang in co-management and reforestation initiatives will be critical to achieving both local development and climate-mitigation objectives.

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Author Contributions
Formal analysis, investigation, resources, data curation, writing-original draft preparation, A.M.; conceptualization and methodology, validation, writing—review and editing, and supervision, M.K.

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Conflicts of Interest
The authors declare no conflict of interest.

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