TATA LOKA
VOLUME 28 NOMOR 1, FEBRUARI 2026, 27-41
P ISSN 0852-7458 - E ISSN 2356-0266

Environmental Factors Affecting Carbon Stock in Land Use Rights (HGU) Land in Tanah Laut Regency, South Kalimantan Province

Faktor Lingkungan yang Mempengaruhi Cadangan Karbon pada Tanah HGU di Kabupaten Tanah Laut Provinsi Kalimantan Selatan

Lutfia Nursetya Fuadina[1], Agung Nugroho Bimasena[1], Nur Aliyyah Irsal[1]

Received: 21 April 2025 Accepted: 23 October 2025

Abstract: By granting Land Use Rights (HGU) for plantation and agricultural sectors, which in the future is expected to facilitate carbon trading as well, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN) plays a crucial role in adapting for climate change. However, the authorities claimed that implementing the Polluter Pay Principles (PPP) for companies producing GHG emissions, such as palm oil plantations, are real steps in increasing the potential for carbon absorption and trading in Indonesia. Therefore, efforts are needed to clarify this statement by analyzing the impact of vegetation cover converted from forest to HGU areas towards the carbon stock values. The purpose of this study was to identify the variables influencing the spatial distribution of carbon stock values in the Tanah Laut Regency's HGU area. In order to map regions with high carbon stocks and meet emission reduction goals, the findings are then utilized to generate policy suggestions in the domain of sustainable plantation. The research employed quantitative methods alongside spatial analysis techniques, as well as qualitative methods through interviews with stakeholders in HGU management, including the Ministry of ATR/BPN, the South Kalimantan Regional Office, the Tanah Laut Regency Government, and HGU holders. The analysis results indicate that the carbon stock value differs across each HGU commodity, specifically rubber, cocoa, and palm oil. The mapping results of carbon stock distribution reveal that areas with minimal conversion possess high potential for carbon absorption. The Geographically Weighted Regression (GWR) analysis indicates that each variable influences locations differently. Water quality index and built-up land area show opposite values to carbon stock. The forest area has a positive value so that increasing forest area in a location will be directly proportional to the increase in carbon stock value, while the HGU area has a range of positive to negative values. It is expected that the study's findings will contribute to manage HGU permits more sustainably by taking environmental issues into account, particularly regarding assessing carbon stocks.
Keywords: Land Use, Carbon Stocks, Environmental Factors, Policy, GWR Analysis

INTRODUCTION

Given the limited amount of available land, sustainable ecological factors should be accounted while giving Land Use Rights or *Hak Guna Usaha* (HGU) permits. However, the causes of peatland degradation that lead to peatland fires in South Kalimantan Province are due to the declining amount of mineral land that has to be managed and the false belief that peat is worthless land that needs to be transformed into productive land. Low Carbon Development (LCD) is a key sustainable development concept since it offers a forward-looking perspective on the significance of balancing ecological, social, and economic

[1]Sekolah Tinggi Pertanahan Nasional, Kabupaten Sleman, Indonesia

Correspondence: lutfia.nursetya@stpn.ac.id

DOI: 10.14710/tataloka.28.1.27-41

development in a way that does not negatively affect one another, lowering greenhouse gas emissions, and promoting climate-resilient development (Ministry of PPN/Bappenas, 2022). However, by granting Land Use Rights (HGU) for plantation and farming activities, which facilitate carbon trading, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN) plays a crucial role in preparing for climate change (Pahlevi, 2024), since holders of Land Use Rights (HGU) for plantations must understand that land ownership is not only about utilization but also about the obligation to protect the surrounding environment. One significant step in expanding Indonesia's capacity for carbon trading is the expansion of the number of HGUs that are able to absorb carbon and the implementation of the Polluter Pay Principles (PPP) for businesses that emit greenhouse gases, such as palm oil farms, where many of these plantations are located on peatlands. This step is in line with the peatland restoration initiatives since peatlands have the capacity to store twice as much carbon globally and four times as much in the atmosphere as forests (Fatkhullah et al., 2021). One of the regions in Indonesia with the greatest spread of peatlands is South Kalimantan Province. In addition to the growing scarcity of mineral soil, fires occur more frequently as a result of natural causes including drought and dry air, as well as the common practices of clearing land.

Since peatlands generate significant amounts of CO_2 emissions from peat forest clearing and peatland draining, environmentalists have taken notice of the rapid changes in peat forest areas (Omar et al., 2022; Saharjo & Novita, 2022). Indonesia has commited to addressing climate change and lowering greenhouse gas (GHG) emissions with the goal of keeping global temperature below 2°C, as seen by its acceptance of the Paris Agreement with Law Number 16 of 2016. Through Presidential Regulation Number 98 of 2021, the government supports this by implementing the Carbon Economic Value, which promotes a green economy and a shift to a low-emission economy, including carbon trading, where Indonesia's tropical rainforests offer a significant potential income of up to IDR 8,000 trillion (Directorate General of Land and Space Control and Order, 2024).

In order to prevent environmental degradation and carbon reduction, the Ministry of ATR/BPN must also support spatial planning policies that explicitly govern efficient land use strategies, such as reforestation, forest conservation, sustainable agriculture, wetland management, urban greening, efficient spatial planning, renewable energy, and mangrove restoration. According to the South Kalimantan Province's Central Statistics Agency report from 2020, the mining industry was the second-largest contributor to the GRDP, followed by the agricultural, forestry, and fisheries sectors. Since these industries are an essential component of the South Kalimantan Province's economy, it is critical that they be handled carefully with attention to environmental sustainability. Monitoring HGU land is one of the efforts. Tanah Laut Regency is one of the regions with the highest number of HGUs in South Kalimantan Province with 151 active HGU around the district. Previous research has concluded that massive changes in land use influence carbon reserve reductions (Sharma et al., 2019; Achmad et al., 2023), and it also involves assessing the value of carbon stores in plantations with the goal of improving sustainable plantation land productivity (Wahyuni et al., 2017; Sugiarto et al., 2024). However, no research has been conducted to link carbon stock reserves to policy formulation in the context of HGU land extension licenses. To fill this gap, the outcomes of this study are expected to provide consideration of environmental factors in the management of HGU permits to make them more sustainable, particularly in considering the value of carbon reserves.

Regardless of whether several plantation activities are acceptable, the South Kalimantan region's plantations, mining regions, and other land uses make for fascinating research subjects. In this instance, to assess ecologically friendly land use regulations as a successful carbon reduction tactic. The fact that Tanah Laut Regency, South Kalimantan, has inappropriate land use and that there are many reports of mismatch between existing land use in the field and the spatial allocation regulated in the HGU which suggests that a lot of variables contribute to these activities being problematic. In the South Kalimantan Province's Tanah Laut Regency, HGU is mostly utilized for oil palm plantations, which have the capacity to both create and absorb carbon. On the other hand, in order to preserve environmental equilibrium, deforestation is an issue that must be assessed. The amount of organic carbon released into the atmosphere is accelerated by growing forest degradation due to deforestation (Avtar, 2022) thus land use change is one of the primary factors causing GHG emissions.

To find out how well a land cover area can absorb carbon, prospective carbon stocks based on land cover must be calculated (Fadhli et al., 2021). According to Setiawan et al., (2016), if land use with a high biomass content changes, land use with a low biomass content will create less carbon since each land use has a different carbon store. The value of carbon stocks, including carbon in the soil, vegetation stands, and plant litter biomass, is impacted by changes in the physical characteristics of the land. Four factors consist of the Water Quality Index, forest cover area, plantation HGU land area, and built-up land area are chosen as independent variables in this study since they are thought to have an impact on the spatial distribution tendency that influences the value of carbon stocks. The selection of various variables is in line with the study conducted by Edwin (2016) which states that carbon stock assessment is not only limited on forest vegetation, but also on soil including agricultural or plantation land, since globally, SOC (soil organic carbon) stock is the largest terrestrial organic carbon reserve. The aim of this study is to identify the variables influencing the spatial distribution of carbon stock values and formulate policy recommendations regarding HGU land supervision in the Tanah Laut Regency. Therefore this study advances the literature on carbon stock analysis by integrating spatial regression techniques (GWR) with policy-oriented land management analysis, thereby enriching debates on sustainable plantation governance in the future.

METHOD

This research was conducted in Tanah Laut Regency, South Kalimantan Province to observe HGU land. Geographically, Tanah Laut Regency is located between 114° 30’20’’ BT – 115° 23’31’’ BT and 3° 30’33’’ LS – 4° 11’38’’ LS. Tanah Laut Regency consists of 11 sub-districts, namely Panyipatan, Takisung, Kurau, Bumi Makmur, Bati-Bati, Tambang Ulang, Pelaihari, Bajuin, Batu Ampar, Jorong, and Kintap. Tanah Laut Regency is one of the areas with the largest number of HGU in South Kalimantan Province, with 135 villages and subdistrict spread across the regency. The total area of Tanah Laut Regency is 3,841.37 Km^2. The study used a combination of quantitative approaches with spatial analysis methods to identify the factors influence carbon stocks value, and qualitative methods in the form of interviews with parties involved in the management of HGU (Ministry of ATR/BPN, South Kalimantan Regional Office, Tanah Laut Regency Government and HGU holders) in order to formulate the policy recommendation related to control HGU. The materials used in this study consisted of Landsat imagery, thematic maps (obtained from the Ministry of ATR/BPN, the South Kalimantan Provincial Environmental Service), and documents of Tanah Laut Regency obtained from Indonesian Bureau of Statistic. We used ArcGIS 10 software to support the spatial statistic analysis.

Secondary data obtained from the Ministry of ATR/BPN, South Kalimantan Provincial Office, consists of:

- Spatial Plan Map obtained from the Tanah Laut Regency Government;
- Land Use Rights (HGU) data obtained from the Ministry of ATR/BPN, South Kalimantan Provincial Office;
- Tanah Laut Regency Documents in Figures and Village Potential data;

- Environmental quality parameter data obtained from the Environmental Service and the Tanah Laut Regency Government, consisting of carbon emission data, soil and water conservation data, waste management data, and vegetation cover area data;
- Carbon stock value per comodity based on calculation allometric formula for biomass value of several types of commodities commonly planted on agroforestry land (The data was obtained from the 2024 Environmental Quality Index Report Book for Tanah Laut Regency) that is presented in Table 1.

Table 1. Carbon Stocks Value based on Biomass Value

Plantation Commodities	Carbon Stocks Value	Class
Forest	58.79 ton C/hectare	High
Oil Palm	51.34 ton C/hectare	High
Cacao	30.33 ton C/hectare	Low
Rubber	17.5 ton C/hectare	Low

Sources: Public Housing, Residential Areas and the Environment Agency of Tanah Laut Regency

Based on data obtained from the Ministry of Agrarian Affairs and Spatial Planning/BPN Regional Office of South Kalimantan Province, there are 151 active HGUs spread throughout Tanah Laut Regency, with a total area of 1,485,980,475 ha and 19 inactive HGUs covering an area of 17,806,748 ha. HGU classification is based on plantation commodities, consisting of oil palm, cocoa, rubber and other commodities. The data set utilized in this analysis includes dependent data, comprising the carbon stocks value, meanwhile independent data was obtainde from land use maps for the year 2014 created through the visual interpretation of Landsat imagery with a spatial resolution of 15 meters. Carbon stock reserve levels were classed by commodity in accordance with World Agroforestry Center calculations as indicated in the Environmental Quality Index Report Book for Tanah Laut Regency). The research flowchart can be explained as Figure 1.

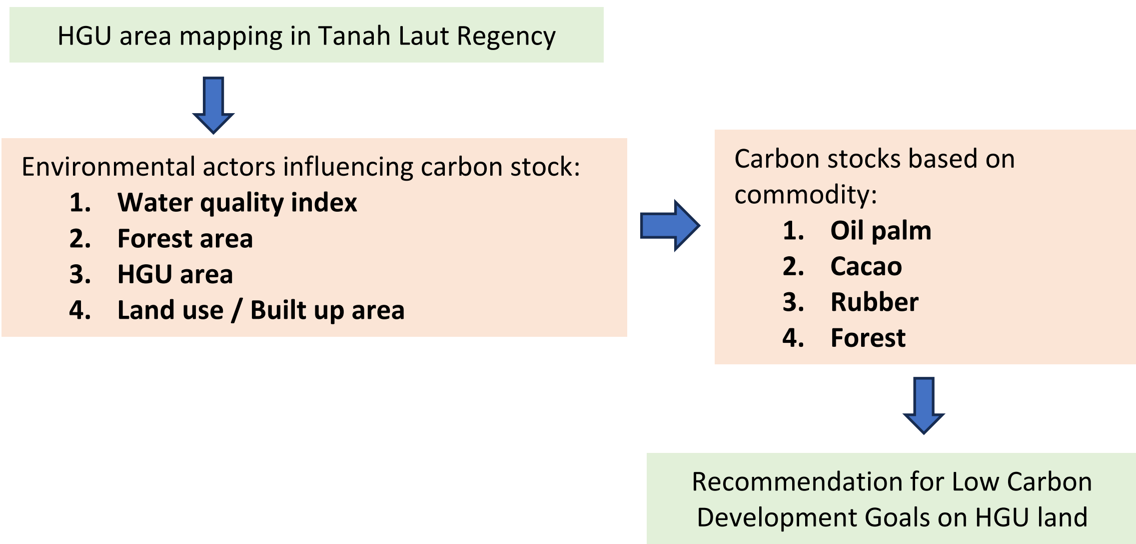
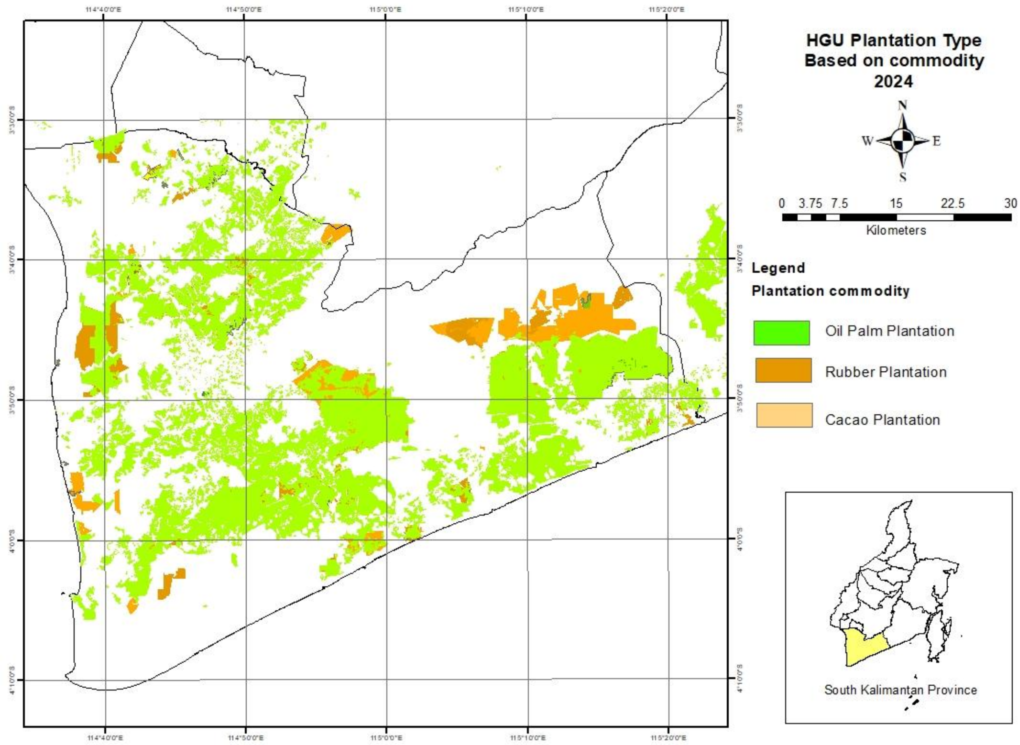


Figure 1. Research Framework



Source: Ministry of Agraria and Spatial Planning, South Kalimantan

Figure 2. HGU Land Area in Tanah Laut Regency

The data analyzed uses several environmental condition parameters obtained from the Environment and Forestry Service of South Kalimantan Province. The data was analyzed to find the most influential factors in the HGU location using the Geographically Weighted Regression (GWR) method. The formula used in the equation model is represented in following equation:

$$Y_j = C_0(u_j, v_j) + \sum_{i=1}^{p} C_i(u_j, v_j) X_{ij} + \varepsilon_j$$

Yj = Dependent variable for observation j; Xik = Independent variable Xi at location j; uj, vj = Coordinate points for observation location I; C0 (uj, vj) = Intercept for observation data j; Ci (uj, vj) = Coefficient for explanatory variable Xi at location j

The explanatory variables (X) used in this study refer to environmental quality parameter data from the Environment and Forestry Service of South Kalimantan Province and Village Potential (PODES) data. The explanatory variables (X) are as shown in Table 2, namely: X1 = water quality index; X2 = forest area; X3 = plantation HGU area; X4 = built-up or residential land area. The selection of these independent variables has the advantage of being able to incorporate them into the study since they provide location factors for spatial weight (Cao et al., 2025; Purwanto et al., 2025), resulting in a more in-depth understanding of the relationship between carbon stock and land-use management in HGU areas.

Table 2. Objective Variables and Explanatory Variables in the GWR Model

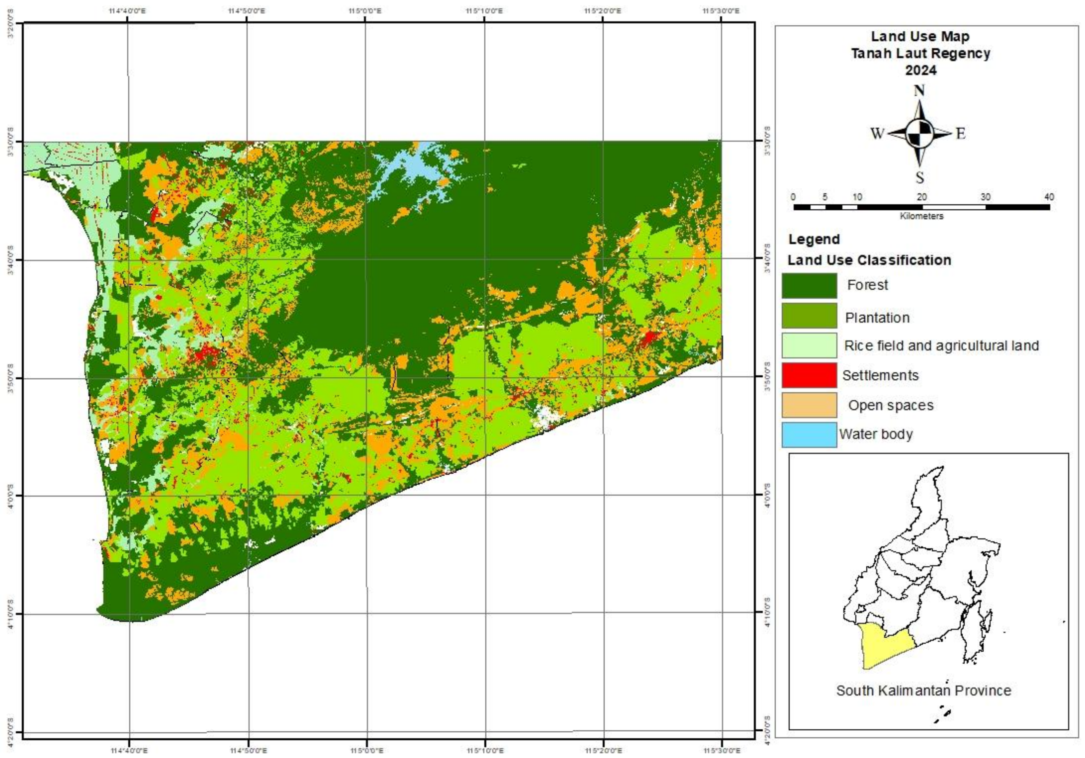
Variable	Variable Code	Explanation
Y	CAR	Carbon stocks value
X_1	IKA	Water quality index
X_2	FOR	Forest area
X_3	HGU	HGU area
X_4	BUA	Built-up area

RESULT AND DISCUSSION

Land Use Analysis

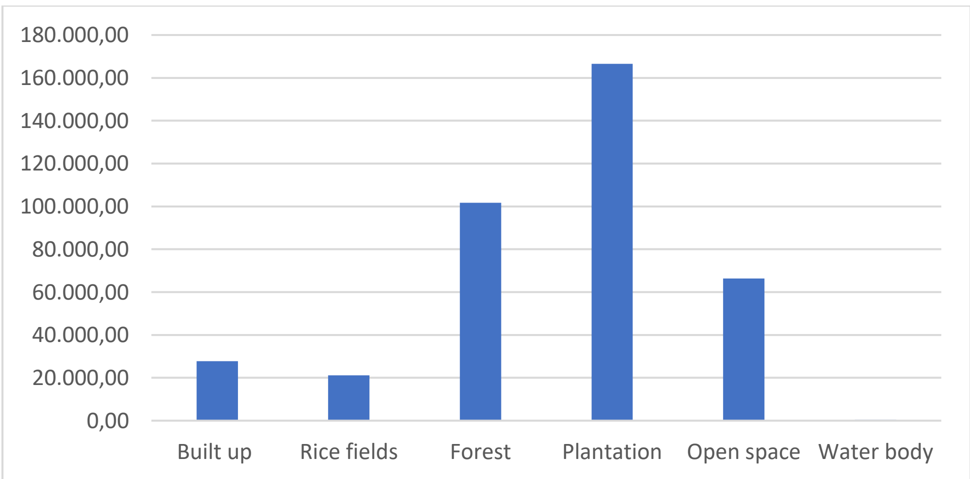
Based on the HGU distribution map in 2024, the largest type of HGU in Tanah Laut Regency is an oil palm plantation located in Jorong Sub-district, with an area of 6,331.80 hectares. Rubber and oil palm are classified as plantation and agricultural sectors commodities that significantly contribute to Indonesia's revenue. In 2020, 208,586 tons of rubber and 1,134,684 tons of palm oil were produced (Ministry of Agriculture, 2023), thus globally, it is recognized as the most productive oil crop and a vital source of vegetable oil (Swaray et al., 2020). The national policy on oil palm plantations also supports the growth in oil palm plantation development in Tanah Laut Regency, which is consistent with the average rise in oil palm plantation land throughout Indonesia after the 2000–2015 period. By 2025, the Ministry of Agriculture aims to cultivate up to 8 million hectares of oil palm (Gunarso et al., 2013). Inevitably, other specified land, whether it be agricultural or forest land, must be converted in order to achieve the intended objective of expanding the amount of HGU land resulted in to the multiple land fires that occur during the dry season, which prevent the rainwater infiltration process. These extensive land clearing for the mining industry and oil palm plantations makes three watershed areas in South Kalimantan—the Batulicin Watershed, Satui Watershed, and Tabunio Watershed—extremely vulnerable to flooding (Auliana et al., 2018). Peat is crucial for preserving the existence of carbon, particularly in relation to the problem of global climate change. Water in degraded peatlands may readily drain out, resulting in peat drought. Peatlands are susceptible to fire during the dry season and eventually dry up (Astuti et al., 2021).

Several land covers in Tanah Laut Regency were categorized into six classes based on the results of the interpretation process that used a combination of RGB 5-4-3 and RGB 4-3-2 channels that shown in Figure 3. These classes include forests, plantations, rice fields and dry land agriculture, open spaces, settlements, and water bodies. According to the interpretation's findings, Tanah Laut Regency's land use is primarily composed of forests, which comprise 101,681.38 hectares (33.10%) and plantation land use types, which total up 166,604.39 hectares (34.84%), as shown in Figure 4.



Source: Ministry of Agraria and Spatial Planning, South Kalimantan

Figure 3. Land Use Map in Tanah Laut Regency



Source: Ministry of Agraria and Spatial Planning, South Kalimantan

Figure 4. Land Use in Tanah Laut Regency

The area of plantation land has exceeded the area of existing forest as shown in Table 3. HGU in the form of oil palm plantations that have been confirmed by the Tanah Laut District Land Office has an area of 23.905,04 Hectares or 39,88% from the total area. While HGU which has not been confirmed by the Tanah Laut District Land Office has an area of 29.394,36 Hectares (49,04%). The results of field observations show that most of the unconfirmed HGU are typical areas around plantation sites that are no longer productive, so some of the areas are utilized by the local community. Among the effects of the enormous growth of oil palm plantations are the decrease in forest area, particularly tropical forests, and agricultural land, mainly rice fields, as well as the growth of settlements and built-up regions. The loss of forest and rice fields can undoubtedly have an adverse effect on environmental conditions and living (Rafli & Buchori, 2022; Amalia et al., 2019). Naturally, the rice supply will be threatened by the shrinking area of rice fields, particularly productive rice fields. Food security in the region will definitely be threatened in the long run by this circumstance. In meanwhile, the threat to endemic species and environmental sustainability may suffer as a result of the decreasing forest areas. This is due to the fact that forests serve as a source of oxygen, an area to store water, a regulator of ecological balance, and many other purposes.

Table 3. HGU in Tanah Laut Regency

HGU type	Area (Hectares)	Area (%)
Forest	14.89	0.02
Cacao	932.57	1.56
Rubber	273.33	0.46
Oil palm	23,905.04	39.88
Shrimp ponds	40.29	0.07
Other Plantation	5,012.96	8.36
Rice fields	15.06	0.03
Poultry	99.50	0.17
Unconfirmed HGU	29,394.36	49.04
Others	254.90	0.43
Total area	59,942.90	100.00

Factors Influencing the Potential for Carbon Reserves in HGU Land

The level of carbon absorption in land is influenced by various factors, including climate, topography, land characteristics, age and density of vegetation, species composition and quality of growing places (Istomo & Farida, 2017). One of the variables influencing variations in the amount of carbon is the types of land cover. The quantity and density of trees, the kinds of trees, and environmental elements that impact the rate of photosynthesis, such as sunshine, water content, temperature, and soil fertility, all determine how much carbon is stored in each type of land cover (Sugirahayu & Rusdiana, 2011). There is a propensity for high carbon storage potential values in the northern portion of HGUland in Tanah Laut Regency, which includes the Sub-districts of Bajuin, Batuampar, Aranio, Karangintan, and Cempaka. These area directly borders the protected forest area, which is a part of the Meratus Mountains and spans eight sub-districts in South Kalimantan Province, including Tanah Laut Regency. The majority of the land cover in these sub-districts is comprised of dense forests since 92,814 hectares (24.6%) of the entire Tanah Laut Regency are designated as protected forest areas. Since tropical forests have a very diverse composition of vegetation species, they are influenced by environmental factors like climate, soil, and light, which combine to form a peak stand. This contributes to the high carbon stock value in the forest ecosystem, particularly in tropical forests (Ariyanti et al., 2018). Since every plant has unique traits and litter decomposition processes, a number of commodities on HGU land also have varying carbon stock distribution values (Figure 5). Meanwhile, the Sub-districts of Pelaihari, Bati-bati, Tambangulang, and Panyipatan have comparatively low carbon stock values. These results are consistent according to earlier research, soil carbon stocks have decreased as a result of land use conversions from forest regions to plantations that cultivate a limited range of primarily annual crops (Koga et al., 2020; Priyadharshini, et al., 2019).

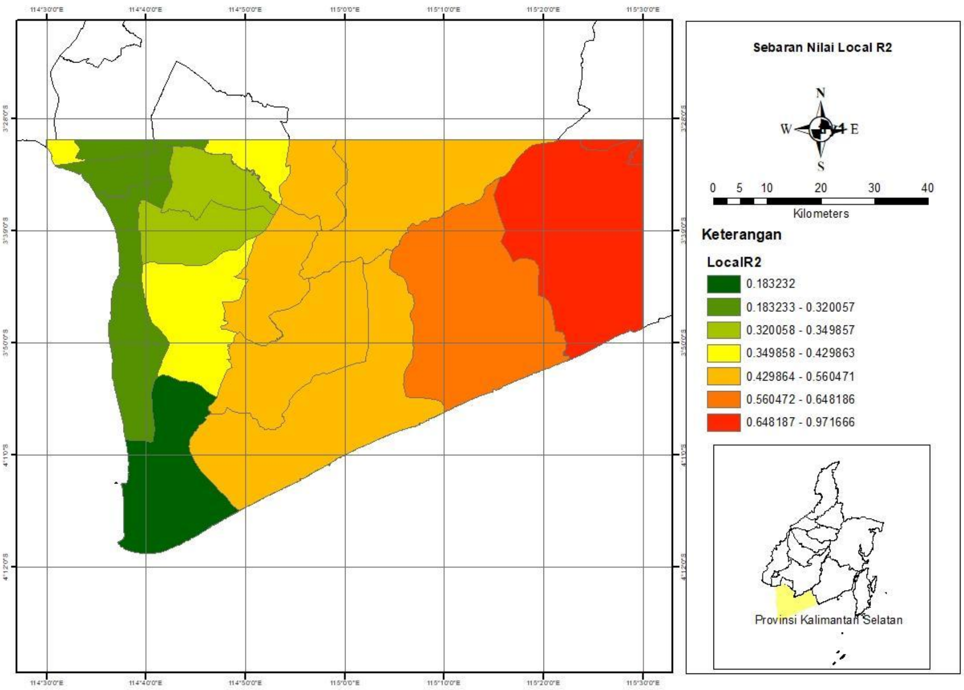


Figure 5. Local R^2 Value Distribution Map

Since Pelaihari Sub-district serves as the capital of Tanah Laut Regency, it has densely populated areas with the increase in settlements, educational and health service facilities and other commercial activities. However, the process of land acquisition and land clearing that take place within some period have implications for massive land use changes. This phenomenon can be attributed to a shift in land use from the areas with high carbon stock reserve values to those with lower carbon stock values (Utami et al., 2024). In general, the four variables entered into the GWR Model are able to explain the distribution of carbon stock values across all sub-districts in Tanah Laut Regency since the local R^2 value is 0.18-0.97. The results of the analysis using the GWR method show that each variable has a different influence on environmental conditions at each HGU location (Pravitasari et al., 2018). Thus, the recommendation will differ based on the carbon absorption potential of each HGU location.

Based on the analysis, the highest local R^2 value is located in the eastern part of the study area shown in red zone (Satui Sub-district and Kintap Sub-district). Areas with higher local R^2 values mean that the 4 variables used in the model are more significant in influencing carbon stock values than other locations. While the lowest local R^2 is located in the southern part of the study area, namely in Panyipatan Sub-district which is shown in green zone (Figure 5). The next analysis result of the GWR model is the value of the coefficient or parameter estimates (C) for each X variable used in the model that presented in Figure 6. In this analysis, four X variables were selected to be used. The four variables are: (1) X1 = Water Quality Index (IKA); (2) X2 = forest area; (3) X3 = plantation HGU area; (4) X4 = built-up land area. The X1 variable entered into the GWR model is the water quality index. All coefficient values or parameter estimates for the water quality index variable are negative, ranging from -0.91 to -4.9. This means that an increase in the value of the water quality index at a site will be inversely proportional to an increase in the value of carbon stocks at that location since the clearer the water measurement findings, the lower the water quality index value (with the value closer to 1). The dark green zone (Beruntungbaru Sub-district) shows the location with the highest influence of the water quality index variable, while the red location (Panyipatan Sub-district) shows the location with the lowest influence of the water quality index variable. This result is consistent with studies conducted by Liu et al. (2025) and Bhatta et al. (2023), which found that water quality and carbon stock are correlated, especially in ecosystems like forests and wetlands where vegetation that functions as a reservoir for carbon is supported by healthy water conditions.

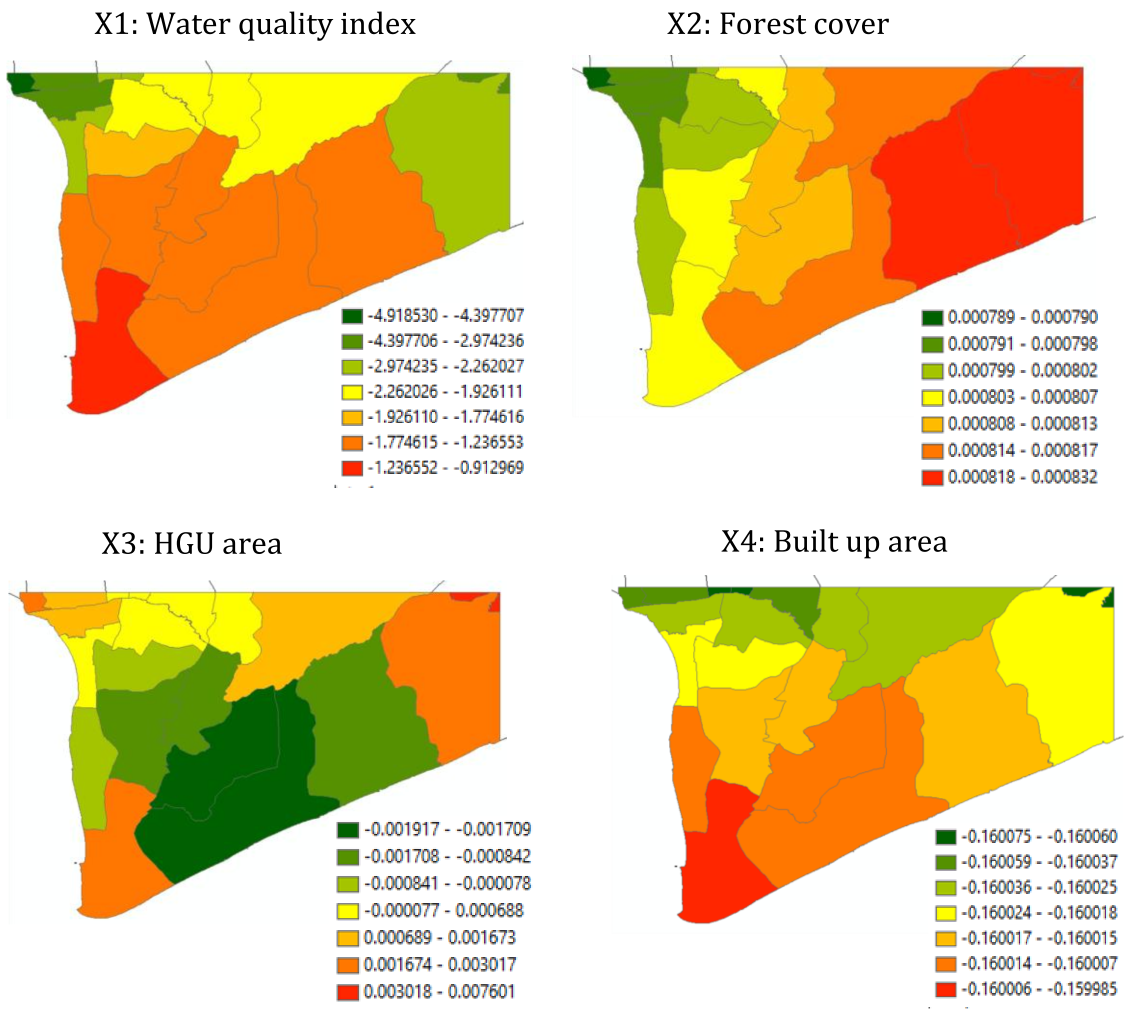


Figure 6. Parameter Estimates (C) Each Variables

The X2 variable employed into the GWR model is the area of forest land. All coefficient values or parameter estimates for forest cover variable are positive, which means that increasing forest area in a location will be directly proportional to the increase in carbon stock value in that location. Areas with wider forest cover will potentially increase the value of carbon absorption both through stands and litter biomass, thereby increasing the value of C-organic and carbon stocks in the soil. The more forests that are damaged, the less the ability of forests function to absorb carbon (Hidayah et al., 2023), this means that there is an increase in carbon emissions into the atmosphere. Improving tropical forest resource conservation is crucial to maximize both carbon sink capacity and economic benefits, as it is important to reduce net emissions and promote sequestration (Murphy, 2024). This could further promote forest carbon trading, which not only provides significant economic advantages to the region but also aids in achieving the national Low Carbon Development targets (Pu et al., 2025).

The X3 variable entered into the GWR model is the area of HGU plantation. When viewed from the range of its values, the magnitude of the coefficient or parameter estimate for the variable area of HGU has a positive range to negative. A positive value means that the magnitude of the influence of X3 is directly proportional to the Y variable which is indicated by the orange and red zones. The increase in the value of the HGU area has different effects on the carbon stock value in oil palm plantations, the carbon stock value is influenced by plant age, land management, and plant density. Conversely, if the coefficient value is negative, it indicates that the magnitude of the influence of X3 is inversely proportional to the Y variable. The locations that have negative parameter estimate values are the green zone, which are located in the southern part of the research location (Jorong Sub-district and Batuampar Sub-district), which indicates that at these locations, the reduction in the area of plantation HGU land will have a significant effect on increasing the carbon stock value. Oil palm commodity is annual plants that have the potential to absorb carbon emissions. The age of oil palm plants can reach more than 20 years. The carbon stored in oil palm plants will change along with the growth and development of the plants.

Carbon stocks in oil palm plantation comprise aboveground biomass (stems, leaves, and fresh fruit bunches), belowground biomass (roots), and soil organic matter. The presence of plant metabolism and absorption of nutrients by roots from the soil will cause increased plant growth. The rate of plant growth will be influenced by the fertility conditions of the soil where the plant is located (Anggraini, 2019). Additionally, previous studies showed that under plantation soils, particularly oil palm and rubber, bacterial communities generated by the roots like Verrucomicrobia and Actinobacteria are more prevalent compared to natural forests (Manpoong et al., 2025), which promote production of organic substances that helps in binding soil microaggregates and converting them into macroaggregates in these plantations soil, suggesting they enhance soil stability, improve the ecosystem plantation and organic matter accumulation, therefore increasing carbon store as well (Inayah et al., 2022). Consequently carbon stocks in HGU, particularly oil palm plantations, can be increased through sustainable practices such as incorporating biomass residues into soil, planting cover crops, and avoiding peatland conversion. These management practices support the Roundtable on Sustainable Palm Oil (RSPO), which aim to reduce the carbon footprint and climatic impact of oil palm agriculture (Siallagan et al., 2025).

The X4 variable entered into the GWR model is the built-up area. All coefficient values or parameter estimates for the built-up area variable are negative. This means that the built-up land area at a location will be inversely proportional to the increase in carbon stock value at that location. The expansion of settlements can have a major effect on the carbon storage capacity of regional ecosystems and extend on ecologically vital areas, such as agricultural land and forests. One of the primary drivers of carbon loss and decreased carbon sink value to economies is the conversion of agriculture to built-up land (Wu, 2023; Xiong et al, 2025). This condition is due to the fact that land parcels are predominantly utilised as built-up land, resulting in a low level of carbon stock reserves since land cover change will change the albedo, especially where green plant surfaces are replaced by non-plant surfaces (Utami et al., 2024). The dark green zone (Lianggang Sub-district) shows the location with the highest influence of the built-up land area variable, while the red location (Panyipatan Sub-district) shows the location with the lowest influence of the built-up land area variable. To achieve the Low Carbon Development goals, it is imperative that future land use change be regulated in consideration of the spatial heterogeneity analysis of regional carbon storage.

CONCLUSION

Monitoring HGU land is one of the crucial efforts to achieve Low Carbon Development (LCD) goals as part of a sustainable plantation approach by controlling the land use changes and the quality of environmental parameters. Tanah Laut Regency land cover is dominated by oil palm plantations that have the function to absorb carbon, even though the amount of carbon reserves is less than the previous land use in the form of tropical forest, which was affected by high biomass content changes. Land use with a low biomass content will create less carbon since each land use has a different carbon store value. Relying solely on natural regulation is insufficient to mitigate the global warming caused by greenhouse gases; instead, long-term effective methods from an economic and scientific standpoint must be investigated, along with reasonable recommendations on how forests can achieve the maximum carbon sequestration particularly in HGU land. Stakeholders need to undertake environmental monitoring efforts to prevent future carbon loss and achieve the goal of sustainable agriculture. Furthermore, political and economic interventions emphasizing environmental sustainability and decarbonization measures must be utilized in HGU management in order to alleviate further climate change impact.

The Ministry of ATR/BPN, South Kalimantan Provincial Office and the Tanah Laut Regency Land Office recommend the use of RDTR and AMDAL in order to control HGU. However, the implementation of HGU monitoring and evaluation, in practice, is only carried out by the ATR/BPN and coordinated by the Dispute Control and Handling Section of the ministry, without involving other parties. Environmental issues such as carbon absorption conditions, flood impacts, and others have not been the concern of ATR/BPN in supervising HGU land. The results of interviews with the Ministry of ATR/BPN, the Department of Agriculture, Food Crops and Plantations of Tanah Laut Regency, the Department of Public Housing, Settlement and Environment of Tanah Laut Regency, and the Department of PUPR in South Kalimantan Province provide information on several problems in the supervision and control of the environmental quality of HGU lands in Tanah Laut Regency, including: (1) The Department of Environment Environmental Agency (DPRKPLH Tanah Laut Regency) is solely responsible for monitoring environmental conditions; the Ministry of ATR/BPN has not been involved in HGU land supervision in relation to environmental conditions; (2) In addition, there are mining activities on HGU land, which is a type of activity that does not comply with its designation or restrictions.

A substantial portion of HGU are classed as abandoned land, hence not all areas in the HGU are considered as productive plantation land: (1) Environmental specialists are not employed by all HGU companies. Therefore, there hasn't been any consistent attempt to quantify the amount of carbon stored in soil; (2) The HGU holder that violates environmental control laws is not subject to severe penalties; (3) Due to a lack of both quantity and quality human resources, a good system for environmental quality supervision has not yet been established. Additionally, there is no synergy model for collaboration in environmental control between the Ministry of ATR/BPN, the Department of PUPR, the Environmental Agency.

Interview results also highlight that stakeholders do not work together to supervise activity on HGU property in the near future. Given that oil palm has become a focal point internationally due to environmental issues such as deforestation, land fires, and peatland degradation, along with social issues like violations of indigenous peoples' rights, improved coordination among stakeholders is essential for effectively monitoring business activities on HGU land to achieve low-carbon development goals and sustainable management practices. Therefore, to meet low-carbon development targets and maintain environmental sustainability and balance, a cooperative commitment is required to monitor efforts in the management practices of plantation HGU land, particularly oil palm. Even though HGU can be awarded the property with management and ownership rights, HGU holders are subject to distinctive obligations, particularly if those conditions are directly connected to the public interest. To achieve sustainable HGU management based on the following low-carbon development goals, stakeholders must collaborate to ensure that HGU supervision is carried out as efficiently as possible applying the procedures outlined below: (1) Implementation of land conversion rules, as well as a prohibition on burning mineral soil and peatland for land clearing; (2) When monitoring plantation HGU (HGU) licenses, the potential carbon sequestration value must be considered to avoid causing damage to land with high carbon sequestration capacity; (3) The carbon content of biomass and standing stock, as well as the Soil Organic Carbon (SOC) value, can be measured on a regular basis as part of the Environmental Quality Index (IKLH) monitoring operations; (4) The parties that provide HGU permits—the Ministry of Agrarian Affairs and Spatial Planning (ATR/BPN), the Public Works and Spatial Planning Agency, and the Environmental Agency—must collaborate in routine environmental control monitoring operations on plantation HGU landholdings.

ACKNOWLEDGEMENT

We would like to express our gratitude to the parties who have assisted in the implementation of this research, consisting of the National Land College, the Ministry of Agrarian Affairs and Spatial Planning/BPN Regional Office of South Kalimantan Province, and the Ministry of Agrarian Affairs and Spatial Planning/BPN Regional Office of Tanah Laut Regency; Tanah Laut District Government, especially the Environmental and Public Works Service.

REFERENCES

Achmad, A., Ramli, I., & Nizamuddin, N. (2023). Impact of land use and land cover changes on carbon stock in Aceh Besar District, Aceh, Indonesia. *Journal of Water and Land Development*, (57), 159-166. DOI: 10.24425/jwld.2023.145346.

Amalia, R., Dharmawan, A. H., Prasetyo, L. B., & Pacheco, P. (2019). Perubahan tutupan lahan akibat ekspansi perkebunan kelapa sawit: Dampak sosial, ekonomi dan ekologi. *Jurnal ilmu lingkungan*, *17*(1), 130-139. DOI: https://doi.org/10.14710/jil.17.1.130-139.

Anggraini, S. A. R. I., & Afriyanti, N. (2019). Estimasi Cadangan Karbon Kelapa Sawit Bibit Bersertifikat pada Perkebunan Kelapa Sawit Kabupaten Serdang Bedagai Sumatera Utara. *Agroprimatech*, *3*(1), 11-16.

Ariyanti, D., Wijayanto, N., & Iwan, H. (2018). The Diversity of Plant and Carbon Stock in Various Types of Land Use in Pesisir Barat Regency of Lampung Province. *Jurnal Silvikultur Tropika*, 09(3), 167–174. DOI: https://doi.org/10.20886/jai.2019.2.2.75-90.

Astuti, K. S., Ridwan, I., & Sudarningsih, S. (2021). Analisis Tingkat kekeringan lahan gambut di Kalimantan Selatan berdasarkan data citra landsat 8 OLI/TIRS. *Jurnal Fisika Flux: Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat*, *18*(2), 119-132. DOI: https://doi.org/10.20527/flux.v18i2.9480.

Auliana, A., Ridwan, I., & Nurlina, N. (2017). Analisis Tingkat Kekritisan Lahan di DAS Tabunio Kabupaten Tanah Laut. *Positron*, *7*(2), 54-59.

Avtar, R., Rinamalo, A. V., Umarhadi, D. A., Gupta, A., Khedher, K. M., Yunus, A. P., ... & Sakti, A. D. (2022). Land use change and prediction for valuating carbon sequestration in Viti Levu Island, Fiji. *Land*, *11*(8), 1274. DOI: https://doi.org/10.3390/land11081274.

Bhatta, M., & Joshi, R. (2023). Assessment of water quality with comparative study of soil organic carbon stock in Nagdaha Lake and its adjacent agricultural land of Lalitpur, Nepal. *International Journal of Bonorowo Wetlands*, 13(1), 9-14. DOI:10.13057/bonorowo/w130102.

Cao, J., Chen, Y., Hu, Y. Zhang, J., Chen, Y., Yang, B., & Wu, S. (2023). Spatiotemporal Trends of Forest Carbon Stock and Its Response to Environmental Factors in the Yangtze River Basin during 2005–2020. Forest, 14(9), 1793. DOI: https://doi.org/10.3390/f14091793.

Directorate General of Land and Space Control and Order. (2024). *National Working Meeting Presentation: National Priority Completion Points for Agrarian Reform.*

Edwin, M. (2016). Penilaian stok karbon tanah organik pada beberapa tipe penggunaan lahan di Kutai Timur, Kalimantan Timur. *Jurnal Agrifor*, 15(2), 279–286.

Fadhli, R., Sugianto, S., & Syakur, S. (2021). Analisis Perubahan Penutupan Lahan dan Potensi Karbon di Taman Hutan Raya Pocut Meurah Intan, Aceh Indonesia. *Jurnal Ilmu Lingkungan*, 19(2), 450–458. DOI: https://doi.org/10.14710/jil.19.2.450-458.

Fatkhullah, M., Mulyani, I., & Imawan, B. (2021). Strategi pengembangan masyarakat petani lahan gambut melalui program tanggung jawab sosial perusahaan: Analisis pendekatan penghidupan berkelanjutan. *Journal of Social Development Studies*, 2(2), 15–29.

Gunarso, P., Hartoyo, M. E., & Agus F. (2013). *Oil Palm and Land Use Change in Indonesia, Malaysia, and Papua New Guinea*. In: Killeen T, Goon J, editors. Reports from the Science Panel of the Second RSPO GHG Working Group. Kuala Lumpur, Malaysia: Roundtable for Sustainable Palm Oil.

Hidayah, E. N., Fithria, A., & Pitri, R. M. N. (2023). Estimasi Stok Karbon Pada Tutupan Lahan Hutan, Pemukiman Dan Lahan Terbuka Di Desa Mandiangin Barat. *Jurnal Sylva Scienteae*, 6(2), 217-225. DOI: https://doi.org/10.20527/jss.v6i2.8504.

Inayah, M. N., Lestari, Y., & Meryandini, A. (2022). Community of Soil Actinobacteria in PTPN VI Oil Palm Plantation Jambi (Sumatra, Indonesia) Based on Amplicon Sequencing of 16S rRNA Gene. *HAYATI Journal of Biosciences*, *29*(3), 389-398. DOI:10.4308/hjb.29.3.389-398.

Istomo, I., & Farida, N. E. (2017). Potensi Simpanan Karbon Di Atas Permukaan Tanah Tegakan Acacia nilotica L. (Willd) ex. Del. Di Taman Nasional Baluran, Jawa Timur. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan*, 7(2), 155–162. DOI: https://doi.org/10.29244/jpsl.7.2.155-162.

Koga, N., Shimoda, S., Shirato, Y., Kusaba, T., Shima, T., Niimi, H., ... & Atsumi, K. (2020). Assessing changes in soil carbon stocks after land use conversion from forest land to agricultural land in Japan. *Geoderma*, *377*, 114487. DOI: https://doi.org/10.1016/j.geoderma.2020.114487.

Liu, S., He, S., & Chen, S. (2025). Potential carbon stock distribution of mangrove and synergistic effect of ecosystem services in China. *Ecological Indicators*, *178*, 113931. DOI: https://doi.org/10.1016/j.ecolind.2025.113931.

Manpoong, C., Tripathi, S. K., Aravindakshan, S., & Krupnik, T. J. (2025). Digging in: Impact of land use changes on soil aggregation patterns and carbon stocks in the moist tropics of the Mizoram in the Indomalayan realm. *Total Environment Advances*, *13*, 200119. DOI: https://doi.org/10.1016/j.teadva.2024.200119.

Ministry of Agriculture. (2023). *Outlook Komoditas Perkebunan. Pusat Data dan Sistem Informasi Pertanian. Sekretariat Jenderal Kementerian Pertanian.*

Ministry of PPN/Bappenas. (2022). *Strategi nasional pengelolaan lahan basah: Ekosistem gambut dan mangrove untuk mencapai tujuan pembangunan berkelanjutan dan pembangunan rendah karbon menuju visi Indonesia 2045. Low Carbon Development Indonesia.*

Murphy, D. J. (2024). Carbon sequestration by tropical trees and crops: A case study of oil palm. *Agriculture*, *14*(7), 1133. DOI: https://doi.org/10.3390/agriculture14071133.

Omar, M. S., Ifandi, E., Sukri, R. S., Kalaitzidis, S., Christanis, K., Lai, D. T. C., ... & Tsikouras, B. (2022). Peatlands in Southeast Asia: A comprehensive geological review. *Earth-Science Reviews*, *232*, 104149. DOI: https://doi.org/10.1016/j.earscirev.2022.104149.

Pahlevi, W. (2024). FOLU NET ZINK 2030: Menata Agraria menuju Hak Guna Usaha Jasa Lingkungan untuk Carbon Trading. *Tunas Agraria*, 7(3), 415-430, DOI: https://doi.org/10.31292/jta.v7i3.368.

Pravitasari, A.E., Rustiadi E., Mulya S.P., Setiawan, Y., Fuadina, L.N., & Murtadho, A. (2018). Identifying the Driving Forces of Urban Expansion and Its Environmental Impact in Jakarta-Bandung Mega Urban Region. *IOP Conf. Series: Earth and Environmental Sciences*, 149, 1-10.

Priyadarshini, R., Hamzah, A., & Widjajani, B. W. (2019). Carbpn Stocks Estimates due to Land Cover Changes at Sumber Brantas Sub-Watershed, East Java. *Journal of Sustainable Agriculture*. 34(1), 1-12. DOI: http://dx.doi.org/10.20961/carakatani.v34i1.27124.

Pu, M., Yang, S., Chen, A., & Deng, Z. (2025). Research on Forest Carbon Sequestration and Its Economic Valuation: A Case Study of the Zixi Mountain Nature Reserve, Chuxiong Prefecture. *Plants*, *14*(17), 2746. DOI: https://doi.org/10.3390/plants14172746.

Purwanto, A., & Mustikarani, W. (2025, March). An assessment of high carbon stock and high conservation value approaches in Mandor Nature Reserve Based on Geospatial. *IOP Conference Series: Earth and Environmental Science*, 1462(1), 012022. , DOI 10.1088/1755-1315/1462/1/012022.

Rafli, M., & Buchori, I. (2022). Dampak ekspansi kebun kelapa sawit terhadap kondisi jasa lingkungan provinsi riau. *Jurnal Pembangunan Wilayah dan Kota*, *18*(2), 98-111. DOI: 10.14710/pwk.v18i2.21229.

Saharjo, B. H., & Novita, N. (2022). The high potential of peatland fires management for greenhouse gas emissions reduction in Indonesia. *Journal of Tropical Silviculture*, *13(1), 53-65.*

Setiawan, G., Syaufina, L., & Puspaningsih, N. (2016). Estimation of Carbon Stock Loss from Land Use Changes in Bogor Regency. *Jurnal Silvikultur Tropika*, 07(2), 79–85.

Sharma, G., Sharma, L. K., & Sharma, K. C. (2019). Assessment of land use change and its effect on soil carbon stock using multitemporal satellite data in semiarid region of Rajasthan, India. *Ecological Processes*, *8*, 42. DOI: https://doi.org/10.1186/s13717-019-0193-5.

Siallagan, E. J., Siregar, Y. I., Nofrizal, N., & Ismail, U. P. (2025). Engineering carbon dynamics and vegetation indices in oil palm plantations: An integrated assessment of carbon stocks, normalized difference vegetation index, and net ecosystem exchange in Riau Province. *Journal of Ecological Engineering*, *26*(2), 342-349. DOI: https://doi.org/10.12911/22998993/197408.

Sugiarto, A., Utaya, S., Bachri, S., & Shrestha, R. P. (2024). Estimation of carbon stocks and CO2 emissions resulting from the forest destruction in West Kalimantan, Indonesia. *Environmental Challenges*, *17*, 101010. DOI: https://doi.org/10.1016/j.envc.2024.101010.

Sugirahayu, L., & Rusdiana, O. (2011). Perbandingan Simpanan Karbon pada Beberapa Penutupan Lahan di Kabupaten Paser, Kalimantan Timur Berdasarkan Sifat Fisik dan Sifat Kimia Tanahnya. *Jurnal Silvikultur Tropika*, 2(3), 149–155.

Swaray, S., Din Amiruddin, M., Rafii, M. Y., Jamian, S., Ismail, M. F., Jalloh, M., ... & Yusuff, O. (2020). Influence of parental dura and pisifera genetic origins on oil palm fruit set ratio and yield components in their D× P Progenies. *Agronomy*, *10*(11), 1793. DOI: 10.3390/agronomy10111793.

Utami, W., Sugiyanto, C., Rahardjo, N. (2024). Analysing the Driving Forces of Carbon Stock Change for Climate Change Mitigation. *Ecological Engineering & Environmental Technology*, 25(11), 83-101. DOI: https://doi.org/10.12912/27197050/192222.

Wahyuni, M., Djaingsastro, A. J., & Arifin, M. (2017). The Estimation of Carbon Stocks on Palm Oil Plant (Elaeis guineensis Jacq) in Smallholder and State Plantation in Indonesia. *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, 33(1), 291-299.

Wu, L. (2023). Sequestering Organic Carbon in Soils through Land Use Change and Agricultural Practices: A Review. Frontiers of Agricultural Science and Engineering, 10(2), 210-225. DOI: 10.15302/J-FASE-2022474.

Xiong, Z., Zhang, Y., Liu, M., Gao, Y., & Gu, T. (2025). Assessing land urbanization and ecological planning impact on carbon stock and its economic value from coupled InVEST-PLUS models. *Scientific Reports*, 15, 30494.