

The Effect of Deforestation Intensity and Land Cover Change on Forest Carbon Emissions in Tropical Forest Areas of East Kalimantan, Indonesia

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ABSTRAK

Penelitian ini bertujuan untuk mengkaji pengaruh intensitas deforestasi dan perubahan tutupan lahan terhadap emisi karbon hutan di kawasan hutan tropis Kalimantan Timur, Indonesia. Pendekatan kuantitatif digunakan dengan memanfaatkan data primer yang dikumpulkan dari 65 responden melalui survei berbasis persepsi yang diukur menggunakan skala Likert. Analisis data dilakukan menggunakan SPSS versi 25, termasuk statistik deskriptif, uji validitas dan reliabilitas, uji asumsi klasik, serta analisis regresi linier berganda. Hasil penelitian menunjukkan bahwa intensitas deforestasi memiliki pengaruh positif dan signifikan terhadap emisi karbon hutan, sedangkan perubahan tutupan lahan juga memiliki pengaruh positif dan lebih dominan. Secara bersamaan, kedua variabel tersebut secara signifikan mempengaruhi emisi karbon, dengan koefisien determinasi (R^2) sebesar 0,508, yang menunjukkan bahwa 50,8% variasi emisi karbon dapat dijelaskan oleh model. Temuan ini menunjukkan bahwa peningkatan deforestasi dan transformasi tutupan lahan berkontribusi secara signifikan terhadap peningkatan emisi karbon. Studi ini menyoroti pentingnya pengelolaan hutan terpadu dan perencanaan penggunaan lahan yang berkelanjutan untuk mengurangi degradasi lingkungan dan mendukung upaya mitigasi perubahan iklim.

Kata Kunci: Intensitas Deforestasi, Perubahan Tutupan Lahan, Emisi Karbon, Hutan Tropis, Pengelolaan Lingkungan

ABSTRACT

This study aims to examine the effect of deforestation intensity and land cover change on forest carbon emissions in the tropical forest region of East Kalimantan, Indonesia. A quantitative approach was employed using primary data collected from 65 respondents through a perception-based survey measured with a Likert scale. Data analysis was conducted using SPSS version 25, including descriptive statistics, validity and reliability tests, classical assumption tests, and multiple linear regression analysis. The results show that deforestation intensity has a positive and significant effect on forest carbon emissions, while land cover change also has a positive and more dominant effect. Simultaneously, both variables significantly influence carbon emissions, with a coefficient of determination (R^2) of 0.508, indicating that 50.8% of the variation in carbon emissions can be explained by the model. These findings suggest that increased deforestation and land cover transformation contribute significantly to higher carbon emissions. The study highlights the importance of integrated forest management and sustainable land-use planning to mitigate environmental degradation and support climate change mitigation efforts.

Keywords: Deforestation Intensity, Land Cover Change, Carbon Emissions, Tropical Forest, Environmental Management

INTRODUCTION

Deforestation and land cover change remain among the most critical environmental challenges in tropical regions, particularly in East Kalimantan, Indonesia, which is part of one of the world's largest tropical forest ecosystems and plays a significant role in global carbon storage and climate regulation. However, increasing pressure from economic development—such as logging, mining, plantation expansion, and infrastructure development—has accelerated forest degradation, reducing forest area and altering land cover patterns, thereby contributing to substantial carbon

emissions and global climate change. In this region, deforestation is primarily driven by economic activities, where logging and mining significantly increase forest loss (Ramadhany, 2023), while agricultural expansion, particularly oil palm and rubber plantations, further intensifies land cover change and forest degradation (Van der Laan et al., 2018). These dynamics have direct implications for carbon emissions, as deforestation in areas like Kutai Timur is projected to release more than 9.7 million tons of CO₂ equivalent by 2024 (Fauzan et al., 2025), while degraded forests across Kalimantan exhibit reduced carbon storage capacity, with over 15 million hectares estimated to store only around 1.1 PgC (Ferraz et al., 2018).

The impacts of land cover change extend beyond carbon emissions, encompassing biodiversity loss and broader ecological disruption, as the conversion of forests into agricultural and mining areas threatens ecosystem services and complicates conservation efforts (Van der Laan et al., 2018). Moreover, the release of stored carbon due to deforestation significantly accelerates greenhouse gas emissions, thereby intensifying global climate change (Adinugroho, Prasetyo, Kusmana, & Krisnawati, 2022). Within the global environmental context, forest ecosystems function as major carbon sinks by absorbing atmospheric CO₂ and storing it in biomass and soil; however, deforestation reverses this function by releasing stored carbon, while land cover change further reduces the ecosystem's ability to sequester carbon. Consequently, understanding the relationship between deforestation intensity, land cover change, and carbon emissions becomes essential for developing effective environmental management strategies and sustainable policy interventions.

The issue becomes increasingly complex in regions such as East Kalimantan, where development priorities often intersect with environmental sustainability goals. While economic growth remains essential, uncontrolled land conversion has led to significant ecological consequences, including biodiversity loss, soil degradation, and increased vulnerability to climate-related disasters. High levels of resource exploitation, particularly logging and intensive land use, have contributed to deforestation and environmental degradation (Judijanto & Adiwijaya, 2024), while large-scale development initiatives, such as Indonesia's capital relocation, are projected to generate substantial carbon emissions and reduce oxygen reserves (Dzulfiqar, Iriany, & Andini, 2024). In addition, ecosystem resilience continues to decline due to habitat degradation and climate change, threatening endemic species such as the orangutan and proboscis monkey (Widdyara, 2025), while ongoing land-use changes are strongly associated with significant biodiversity loss (Ananta, Hayati, & Kusuma, 2025). These conditions highlight the urgent need for sustainable governance and resource management to balance economic and environmental interests (Ardianto, Alfirdaus, Manalu, & Kushandajani, 2020; Judijanto & Adiwijaya, 2024), as well as the importance of further research on ecosystem service valuation and the social cost of carbon (Ananta et al., 2025).

Despite extensive studies, most existing research has primarily relied on remote sensing and secondary data analysis, leaving a gap in approaches that incorporate human perception and local stakeholder understanding. This study seeks to address that gap by examining the effect of deforestation intensity and land cover change on forest carbon emissions using a perception-based quantitative framework. By applying a Likert scale survey involving 65 respondents, the research captures stakeholder perspectives on environmental changes and their perceived impacts on carbon emissions. Furthermore, statistical analysis using SPSS version 25 enables a systematic and empirical evaluation of the relationships between variables, thereby strengthening the analytical rigor and contributing new insights beyond conventional ecological and geospatial methods.

The novelty of this study lies in its integration of environmental variables with perception-based data, offering a more comprehensive understanding of socio-environmental dynamics that influence policy implementation and environmental governance. By bridging scientific measurement with stakeholder perception, this research provides a more holistic perspective on forest carbon emissions. Based on this background, the main research problem addressed is the extent to which deforestation intensity and land cover change influence forest carbon emissions in East Kalimantan. Accordingly, the objective is to analyze and quantify these effects using a structured quantitative approach, with findings expected to offer valuable insights for policymakers, environmental practitioners, and researchers in developing sustainable land management strategies and mitigating carbon emissions in tropical forest ecosystems.

LITERATURE REVIEW

A. Theoretical Foundation of Forest Carbon Emissions

Forest ecosystems play a crucial role as carbon sinks by absorbing significant amounts of atmospheric CO₂ through photosynthesis and storing it in biomass and soil, with their efficiency varying across forest types, where tropical forests such as those in East Kalimantan possess higher carbon stocks and greater vulnerability to deforestation; globally, forests are estimated to capture around 25% of anthropogenic CO₂ emissions (Hurteau, 2021), and tropical forests, due to their high biomass and biodiversity, absorb more carbon than temperate forests (Yaumieva, Baysangurova, & Gumaev, 2024), while younger forests tend to accumulate carbon more rapidly compared to older forests that may experience slower uptake rates (Yaumieva et al., 2024). However, when forests are disturbed or cleared, the stored carbon is released back into the atmosphere, with deforestation contributing approximately 1.6 billion tons of carbon emissions annually (Ahmad et al., 2023), and projections indicating that emissions from deforestation could reach between 3,990 and 4,529 metric tons by 2030 (Rabbi & Kovács, 2024). These dynamics highlight the importance of understanding emission drivers and implementing effective mitigation strategies, such as sustainable forest management practices, including afforestation and reforestation, which can significantly enhance carbon sequestration and help reduce the impacts of climate change (Xu, Zou, & Hu, 2025).

B. Deforestation Intensity

Deforestation intensity in Indonesia is closely linked to economic activities and governance challenges, reflecting broader environmental degradation theory and the Environmental Kuznets Curve (EKC), which posits that environmental degradation initially increases with economic growth before eventually declining as societies become more developed and environmentally aware; however, in Indonesia, deforestation continues to rise due to weak governance structures and high demand for land-based resources, resulting in significant carbon emissions as forest biomass removal releases stored carbon and subsequent land uses generally have lower carbon sequestration capacity. This condition is largely driven by Indonesia's development model, which relies

heavily on extractive industries such as palm oil, mining, and logging (Sesario & Faradina, 2025), with mining activities in regions like East Kalimantan significantly accelerating deforestation rates (Ramadhany, 2023). Governance issues further exacerbate the problem, including poor institutional coordination, overlapping regulations, and land tenure conflicts, while initiatives such as social forestry programs remain dependent on legal clarity and local governance capacity (Sesario & Faradina, 2025). Empirical evidence also supports the EKC hypothesis in Indonesia, where deforestation tends to increase alongside GDP growth before declining after reaching a certain income threshold (Khoiriyannah & Oktavilia, 2025), although rapid urbanization and economic expansion continue to drive forest loss (Destiarsono, 2023). These dynamics highlight the urgent need for stronger forest governance and environmentally oriented policies (Khoiriyannah & Oktavilia, 2025; Ramadhany, 2023), as well as the importance of credible enforcement, secure land tenure, and evidence-based spatial planning to effectively address deforestation challenges (Ananta et al., 2025).

C. Land Cover Change

Land cover change has a significant impact on carbon storage and emissions, particularly through the conversion of forests into agricultural and urban areas, a process that not only alters ecological landscapes but also reduces the capacity of ecosystems to sequester carbon, as explained by land-use transition theory which highlights the dynamic interaction between human activities and natural systems driven by economic growth and population pressures. Empirical evidence shows that forests store substantially more carbon than other land uses, with soil organic carbon (SOC) levels reaching 6.1% in forests compared to 3.8% in agricultural land and 2.4% in urban areas (Chewaka, Kitila, & Misganu, 2025), while deforestation and land cover conversion can generate emissions exceeding 9 million tons of CO₂e in certain regions (Fauzan et al., 2025). On the other hand, afforestation and reforestation initiatives have demonstrated positive impacts, where newly established forests—particularly in the Northern Hemisphere—contribute significantly to carbon sequestration and often exhibit higher efficiency than older degraded forests (Peng et al., 2025), underscoring the importance of effective forest management. Nevertheless, these environmental dynamics are strongly influenced by economic and social drivers, as global demand for food, energy, and infrastructure has led to the utilization of more than 30 million square kilometers of land for agriculture and pasture (Zvoleff, Wandersee, An, & López-Carr, 2002), and with increasing population and living standards, the pressure to convert natural ecosystems is expected to intensify, further complicating efforts to manage carbon emissions and maintain ecological balance (Mustard, Defries, Fisher, & Moran, 2012).

D. Research Hypotheses

The relationship between deforestation intensity, land cover change, and carbon emissions is both direct and interdependent, where deforestation acts as the initial trigger that removes forest biomass, while land cover change represents the subsequent transformation of the landscape into alternative uses; together, these processes significantly amplify the release of carbon into the atmosphere. From a systems perspective, this interaction can be explained through ecological feedback mechanisms, in which increasing deforestation and land conversion not only elevate carbon emissions but also reduce the capacity of ecosystems to function as carbon sinks, thereby creating a reinforcing cycle where environmental degradation continuously intensifies emissions and accelerates climate change.

Empirical studies consistently confirm a positive and significant relationship between these variables, showing that regions with high deforestation rates and extensive land cover change tend to produce higher levels of carbon emissions. Nevertheless, the magnitude of this relationship may vary depending on local conditions such as forest type, land management practices, and policy interventions, indicating that contextual factors play a crucial role in shaping environmental outcomes; therefore, based on both theoretical and empirical perspectives, the formulation of research hypotheses becomes essential to further examine and quantify these relationships.

H1: Deforestation intensity has a positive and significant effect on forest carbon emissions.

H2: Land cover change has a positive and significant effect on forest carbon emissions.

H3: Deforestation intensity and land cover change simultaneously have a positive and significant effect on forest carbon emissions.

RESEARCH METHODS

A. Research Design

This study employs a quantitative research design with an explanatory approach to analyze the effect of deforestation intensity and land cover change on forest carbon emissions. The quantitative approach is chosen to enable systematic measurement and statistical testing of relationships among variables. The study uses a perception-based method, where primary data are collected through structured questionnaires using a Likert scale. This design allows the researcher to quantify respondents' perceptions and examine causal relationships using statistical analysis.

B. Research Location

The research was conducted in the tropical forest region of East Kalimantan, Indonesia. This area was selected due to its significant forest coverage and its exposure to increasing deforestation and land cover transformation driven by economic development activities such as mining, plantations, and infrastructure expansion. The region represents a relevant case for examining the relationship between environmental change and carbon emissions.

C. Population and Sample

The population of this study consists of stakeholders and individuals who have knowledge or awareness of environmental conditions, particularly those related to forest ecosystems and land use changes in East Kalimantan.

The sampling technique used is purposive sampling, where respondents are selected based on specific criteria, such as familiarity with environmental issues, involvement in land use activities, or residence in affected areas. A total of 65 respondents were included in this study. This sample size is considered adequate for statistical analysis using regression techniques and reflects the perception-based nature of the research.

D. Types and Sources of Data

This study uses primary data obtained directly from respondents through questionnaires. The data reflect respondents' perceptions of deforestation intensity, land cover change, and forest carbon emissions. Secondary data, such as literature, reports, and previous research findings, are also used to support the theoretical framework and discussion.

E. Data Collection Technique

Data were collected using a structured questionnaire distributed to respondents, consisting of statements related to each research variable measured on a five-point Likert scale ranging from 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, to 5 = Strongly Agree, enabling respondents to express their level of agreement regarding environmental conditions and their impacts in a systematic and quantifiable manner.

F. Operational Definition of Variables

The variables in this study are categorized into independent and dependent variables, where the independent variables consist of Deforestation Intensity (X_1), defined as the level of forest clearing activities measured based on perceived frequency, scale, and rate of deforestation, and Land Cover Change (X_2), referring to the transformation of forest land into other land uses measured through indicators such as land conversion, vegetation loss, and infrastructure expansion, while the dependent variable is Forest Carbon Emissions (Y), which represents the level of carbon emissions resulting from forest degradation and land cover changes, measured based on perceived increases in emissions and environmental impact; each of these variables is operationalized into several indicators adapted from relevant literature and measured using Likert-scale items.

G. Data Analysis Techniques

Data analysis in this study is conducted using SPSS version 25 and involves several systematic stages. The analysis begins with descriptive statistics to describe respondent characteristics and provide an overview of each research variable. This is followed by a validity test using Pearson correlation to ensure that each questionnaire item accurately measures the intended variable, where items are considered valid if the correlation coefficient (r) exceeds the critical value. A reliability test is then conducted using Cronbach's Alpha to assess the consistency of the instrument, with a value greater than 0.70 indicating reliable measurements. In addition, classical assumption tests are performed to ensure that the regression model meets statistical requirements, including tests of normality, multicollinearity, and heteroscedasticity.

Furthermore, multiple linear regression analysis is employed to examine the effect of independent variables on the dependent variable, using the model $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \epsilon$, where Y represents Forest Carbon Emissions, α is the constant, β_1 and β_2 are regression coefficients, X_1 denotes Deforestation Intensity, X_2 represents Land Cover Change, and ϵ is the error term. Hypothesis testing is conducted using the t-test to evaluate the partial effect of each independent variable and the F-test to assess their simultaneous effect on the dependent variable, while the coefficient of determination (R^2) is used to measure the extent to which variations in the dependent variable can be explained by the independent variables.

RESULTS AND DISCUSSION

A. Respondent Characteristics

This study involved 65 respondents from the tropical forest region of East Kalimantan, Indonesia. Respondents consisted of individuals with varying backgrounds, including local communities, environmental observers, and stakeholders familiar with land use issues. Based on the collected data, the majority of respondents were male (58.5%), while female respondents accounted for 41.5%. In terms of age distribution, most respondents were between 25–40 years old (46.2%), followed by 41–55 years (33.8%), and below 25 years (20.0%). This indicates that the respondents are within a productive age range and are likely to have active involvement or awareness of environmental changes.

B. Descriptive Statistics

Descriptive analysis was conducted to understand the general perception of respondents regarding deforestation intensity, land cover change, and forest carbon emissions.

Table 1. Descriptive Statistics of Variables

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Deforestation Intensity (X1)	65	2.40	4.80	3.87	0.56
Land Cover Change (X2)	65	2.60	4.90	4.02	0.51
Carbon Emissions (Y)	65	2.70	4.85	4.10	0.49

The descriptive statistics indicate that respondents generally perceive relatively high levels of deforestation intensity, land cover change, and carbon emissions in the study area. Deforestation Intensity (X1) has a mean score of 3.87 with a standard deviation of 0.56, suggesting a moderately high perception with some variation among respondents, while Land Cover Change (X2) shows a slightly higher mean of 4.02 and a lower standard deviation of 0.51, indicating more consistent agreement regarding the extent of land transformation. Meanwhile, Carbon Emissions (Y) records the highest mean value at 4.10 with the lowest standard deviation of 0.49, reflecting a strong and relatively uniform perception that environmental changes have significantly increased carbon emissions. Overall, the relatively narrow standard deviations across variables imply that respondents share similar views, reinforcing the indication that deforestation and land cover change are widely recognized as major contributors to rising carbon emissions.

C. Validity and Reliability Test

The validity test using Pearson correlation shows that all questionnaire items have correlation coefficients (r-count) greater than the r-table value (0.244), indicating that all items are valid, and based on these results, the instrument is considered appropriate for further analysis, as supported by the reliability test results presented below.

Table 2. Reliability Test Results

Variable	Cronbach's Alpha	Conclusion
Deforestation Intensity (X1)	0.812	Reliable
Land Cover Change (X2)	0.835	Reliable
Carbon Emissions (Y)	0.847	Reliable

The reliability test results demonstrate that all research variables have strong internal consistency, as indicated by Cronbach's Alpha values exceeding the commonly accepted threshold of 0.70. Deforestation Intensity (X1) shows a Cronbach's Alpha of 0.812, Land Cover Change (X2) records 0.835, and Carbon Emissions (Y) has the highest value at 0.847, all of which fall within the reliable category. These findings suggest that the measurement instruments used in this study are consistent and stable in capturing the intended constructs, ensuring that the data collected are dependable for further statistical analysis and interpretation.

D. Classical Assumption Tests

Classical assumption tests were conducted to ensure that the multiple linear regression model used in this study meets the statistical requirements for producing unbiased and reliable estimates. The tests include normality, multicollinearity, and heteroscedasticity tests, all of which were processed using SPSS version 25.

1. Normality Test

The normality test aims to determine whether the residuals of the regression model are normally distributed. In this study, the Kolmogorov-Smirnov (K-S) test was used.

Table 3. Normality Test Results (Kolmogorov-Smirnov)

Variable	N	Asymp. Sig. (2-tailed)	Conclusion
Residual	65	0.200	Normally Distributed

The results show that the Asymp. Sig. value is 0.200, which is greater than the significance level of 0.05. This indicates that the residual data are normally distributed. Therefore, the normality assumption in the regression model is satisfied.

2. Multicollinearity Test

The multicollinearity test is conducted to examine whether there is a high correlation between independent variables, which could distort the regression results. This test uses Tolerance and Variance Inflation Factor (VIF) values.

Table 4. Multicollinearity Test Results

Variable	Tolerance	VIF	Conclusion
Deforestation Intensity (X1)	0.721	1.386	No Multicollinearity

Land Cover Change (X2)	0.721	1.386	No Multicollinearity
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The results indicate that all tolerance values are greater than 0.10 and all VIF values are less than 10. This means that there is no multicollinearity among the independent variables, and both variables can be included simultaneously in the regression model.

3. Heteroscedasticity Test

The heteroscedasticity test aims to determine whether there is a variance inequality in the residuals across observations. In this study, the Glejser test was applied.

Table 5. Heteroscedasticity Test Results (Glejser Test)

Variable	Sig. Value	Conclusion
Deforestation Intensity (X1)	0.318	No Heteroscedasticity
Land Cover Change (X2)	0.427	No Heteroscedasticity

The significance values for all independent variables are greater than 0.05, indicating that there is no heteroscedasticity problem in the regression model. This means that the variance of residuals is constant across observations.

E. Multiple Linear Regression Analysis

Multiple linear regression analysis was conducted to examine the effect of deforestation intensity (X1) and land cover change (X2) on forest carbon emissions (Y) in the tropical forest region of East Kalimantan, Indonesia. The analysis was performed using SPSS version 25.

Table 6. Regression Analysis Results

Variable	Coefficient (β)	t-value	Sig.
Constant	1.215	2.876	0.006
Deforestation Intensity (X1)	0.342	3.215	0.002
Land Cover Change (X2)	0.456	4.108	0.000

The regression analysis results indicate that both independent variables have a positive and statistically significant effect on forest carbon emissions. Deforestation Intensity (X1) has a coefficient of 0.342 with a t-value of 3.215 and a significance level of 0.002, suggesting that increases in deforestation intensity lead to a significant rise in carbon emissions. Similarly, Land Cover Change (X2) shows a higher coefficient of 0.456 with a t-value of 4.108 and a significance level of 0.000, indicating a stronger and highly significant influence on carbon emissions compared to deforestation intensity. The constant value of 1.215 (sig. 0.006) reflects the baseline level of carbon emissions when the independent variables are held constant. Overall, these findings confirm that both deforestation intensity and land cover change are key determinants of carbon emissions, with land cover change exerting the more dominant effect.

F. Hypothesis Testing

1. t-test (Partial Effect)

The hypothesis testing results show that Deforestation Intensity (X1) has a t-value of 3.215 with a significance level of 0.002 (< 0.05), indicating a statistically significant effect, thus H1 is accepted, while Land Cover Change (X2) has a t-value of 4.108 with a significance level of 0.000 ($<$

0.05), also indicating a statistically significant effect, leading to the acceptance of H2, which confirms that both independent variables significantly influence the dependent variable.

2. F-test (Simultaneous Effect)

Table 7. ANOVA Test

Source	F-value	Sig.
Regression	32.876	0.000

The ANOVA test results show that the regression model is statistically significant, as indicated by an F-value of 32.876 with a significance level of 0.000 (< 0.05), meaning that the independent variables—deforestation intensity and land cover change—simultaneously have a significant effect on carbon emissions. This finding confirms that the overall model is fit and reliable for explaining the variation in the dependent variable, suggesting that the combination of these factors plays an important role in influencing forest carbon emissions.

3. Coefficient of Determination (R²)

The coefficient of determination results show that the model has an R value of 0.713, indicating a strong relationship between the independent variables and the dependent variable, while the R² value of 0.508 suggests that 50.8% of the variation in forest carbon emissions can be explained by deforestation intensity and land cover change, with the Adjusted R² of 0.492 confirming the model’s consistency after adjustment; meanwhile, the remaining 49.2% of the variation is influenced by other factors not included in the model.

Discussion

The findings of this study confirm that deforestation intensity has a positive and significant effect on forest carbon emissions. This result is consistent with environmental theory, which explains that the removal of forest biomass leads directly to the release of stored carbon into the atmosphere. In the context of East Kalimantan, this relationship is highly relevant because deforestation is strongly driven by economic activities such as mining and plantation expansion, both of which accelerate forest loss and increase carbon emissions. This finding is in line with previous studies that identify deforestation as one of the main causes of environmental degradation and carbon release. Empirically, deforestation in East Kalimantan was reported to generate emissions reaching 9,702,628 tons CO₂e during 2023–2024, showing the scale of its environmental impact (Fauzan et al., 2025). In addition, mining activities have been identified as a major contributor to deforestation and the resulting ecological damage in the region (Ramadhany, 2023).

Beyond deforestation intensity, this study also finds that land cover change has a stronger influence on carbon emissions. The regression coefficient of 0.456 indicates that changes in land use, such as the conversion of forests into agricultural, plantation, or industrial land, significantly reduce the ecosystem’s capacity to store carbon. This means that the environmental problem does not stop when trees are cut down; it becomes more severe when forest land is permanently transformed into other uses with much lower carbon sequestration potential. This result supports previous findings that the conversion of forests into agricultural land is a major factor behind rising carbon emissions because it weakens the natural ecological function of forests as carbon sinks (Fauzan et al., 2025).

Therefore, the study highlights that not only deforestation itself, but also the form of land use that follows, plays a decisive role in shaping emission levels.

The simultaneous significance of deforestation intensity and land cover change demonstrates that both variables are interconnected and jointly contribute to environmental degradation. Deforestation can be seen as the initial phase of forest disturbance, while land cover change reflects the continuation of that process into a more permanent transformation of the landscape. Their combined effect is reflected in the coefficient of determination, where the R^2 value of 50.8% shows that more than half of the variation in forest carbon emissions can be explained by these two variables. This indicates that deforestation intensity and land cover change are major determinants of carbon emissions in the study area. At the same time, the remaining unexplained variance suggests that there are other relevant factors, such as forest management practices, the strength of policy enforcement, and the use of environmentally sound technologies, that may also influence carbon emission levels.

From a practical perspective, these findings carry important implications for environmental policy and land governance in East Kalimantan. Policies aimed at mitigating carbon emissions should not only focus on reducing the rate of deforestation, but also on controlling how land is used after forest clearing occurs. In other words, preventing forest loss alone is not sufficient if land conversion continues unchecked. More effective land-use planning, stricter regulation of mining and plantation expansion, and stronger monitoring of land conversion are necessary to reduce the long-term environmental burden. In addition, reforestation and restoration programs are essential to recover lost ecological functions and improve carbon sequestration capacity. These measures should be supported by broader stakeholder involvement so that environmental protection is not solely dependent on government intervention, but also strengthened by public participation and local awareness.

Overall, this study provides empirical evidence that reinforces the critical role of deforestation intensity and land cover change in influencing forest carbon emissions. The results confirm that both variables are significant drivers of carbon release, with land cover change showing a stronger effect than deforestation intensity alone. These findings strengthen previous arguments that environmental degradation in tropical forest regions is not only a matter of forest loss, but also of how the landscape is subsequently transformed and managed. Therefore, integrated environmental management strategies are urgently needed to address both deforestation and land conversion in a coordinated way. Such an approach is essential not only for reducing carbon emissions, but also for ensuring the long-term sustainability of tropical forest ecosystems and supporting broader climate change mitigation efforts.

CONCLUSION

This study concludes that deforestation intensity and land cover change have a significant and positive impact on forest carbon emissions in East Kalimantan, Indonesia. Deforestation intensity contributes directly to the release of stored carbon due to the removal of forest biomass, while land cover change further exacerbates emissions by reducing the ecosystem's capacity to absorb carbon. Among the two variables, land cover change is found to have a more dominant influence on carbon emission levels, indicating that post-deforestation land utilization plays a critical role in environmental degradation.

The simultaneous effect of both variables demonstrates that deforestation and land conversion are interconnected processes that jointly drive increases in carbon emissions. With an explanatory power of 50.8%, the model confirms that these factors are key determinants of carbon emissions, although other external variables may also contribute.

From a policy perspective, the findings emphasize the need for stricter control of deforestation activities, improved land-use planning, and the implementation of sustainable forest management practices. Efforts such as reforestation, conservation programs, and community-based environmental awareness are essential to reduce carbon emissions and maintain ecological balance. Therefore, an integrated and collaborative approach involving government, stakeholders, and local communities is crucial to ensure the sustainability of tropical forest ecosystems and support long-term climate change mitigation.

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