West Science Agro
Vol. 3, No. 01, February 2025, pp. 84~91

Use of Satellite Technology for Forest Cover Area Monitoring in a Blockchain-Based Carbon Trading Scheme

Haryono
Universitas Bhayangkara Surabaya

Article Info

Article history:

Received February, 2025
Revised February, 2025
Accepted February, 2025

Keywords:

Satellite Technology,
Geographic Information Systems (GIS),
Blockchain,
Carbon Trading,
Forest Monitoring

ABSTRACT

This study explores the utilization of satellite technology, Geographic Information Systems (GIS), and blockchain to enhance forest cover monitoring and enable a transparent carbon trading mechanism. Satellite high-resolution imagery and GIS analysis were applied in estimating forest cover change and carbon sequestration potential. In addition, a blockchain prototype was also developed to automatically issue and exchange carbon credits using smart contracts to ensure transparency and efficiency. Findings indicate a 7.5% reduction in forest cover in the study area over five years, with the highest deforestation hotspots discovered through spatial analysis. The blockchain platform was successful in automating carbon credit transactions with an average processing time of 15 seconds and ensuring secure and immutable records. Stakeholder feedback highlighted the capacity of the system to simplify regulatory oversight and promote trust in carbon marketplaces. The study points to the feasibility and scalability of integrating such technologies to address deforestation, enhance carbon trading mechanisms, and aid global sustainability goals.

Corresponding Author:

Name: Haryono
Institution: Universitas Bhayangkara Surabaya
Email: haryono@ubhara.ac.id

1. INTRODUCTION

Forests are also important in the preservation of the world's ecological balance, acting as carbon sinks and climate regulators. However, the increased deforestation and forest degradation have necessitated an urgent need for effective monitoring and management systems [1], [2]. With increased global efforts in curbing climate change, carbon trading schemes have emerged as a vital mechanism for promoting sustainable action by rewarding emission reduction of greenhouse gases [1], [3]. However, problems of data manipulation, inefficiency in tracing carbon credits, and lack of transparency are limitations to the success of such schemes [2], [4]. As a response to these problems, this study proposes the use of satellite technology and blockchain implementation for tracking forest cover under a carbon trading regime.

Satellite technology based on Geographic Information Systems (GIS) has revolutionized environmental monitoring by enabling precise, real-time, and extensive land cover mapping. Through satellite imagery with high resolution and spatial analysis, GIS provides useful information on forest processes like deforestation rates, canopy cover, and land-use alterations [5], [6]. These points of data are crucial in carbon sequestration measurement, which is a vital parameter in carbon trading schemes. Although accurate, the current carbon credit management system is not secure or resistant to manipulation since no secure and open system exists.

Blockchain technology offers a groundbreaking solution in the form of an immutable, decentralized ledger system for carbon trading. Blockchain ensures transparency, traceability, and security while minimizing the risks of fraud and double counting associated with carbon credit transactions [7], [8]. The integration of satellite-based GIS analysis with blockchain technology forms a robust platform for carbon credit management, stakeholder trust building, and improving the efficiency of carbon trading systems [9], [10].

Deforestation and forest degradation are among the most pressing global challenges, and they contribute significantly to climate change, loss of biodiversity, and environmental instability. Because forests are significant carbon sinks, their preservation is critical to achieving global climate objectives, including the Paris Agreement. The lack of reliable, real-time data on forest cover changes and the inefficiencies in current carbon trading systems, however, impede effective forest preservation. Integration of advanced technologies such as satellite tracking, Geographic Information Systems (GIS), and blockchain has the potential to revolutionize forest management and carbon trading into transparent, efficient, and scalable processes.

The application of REDD+ in East Java is marred by some major challenges that detract from its effectiveness in forest conservation and carbon trade. Ineffective forest monitoring systems employ low-resolution or old data, making it difficult to effectively and in real time track deforestation patterns. Inefficiencies in carbon trading also arise through a lack of transparency, fraud risks, and double counting, which undermines the credibility and effectiveness of existing mechanisms. Limited technological application of technology like satellite imaging, GIS, and blockchain also greatly constrains potential for full management of forest conservation and carbon exchange. Moreover, there exists a pre-existing stakeholder trust deficit due to the absence of transparent and accountable carbon credits issuance, eroding confidence among businesses, governments, and environmental nongovernmental organizations. To overcome such obstacles requires an all-encompassing approach that leverages modern technology to enhance monitoring accuracy, promote transaction safety, and establish trust among the stakeholders.

This paper attempts to explore satellite technology and blockchain usage in a GIS-based framework for forest observation and carbon trade. The study outlines the technical and operational benefits of such an approach, whose capability to enhance precision, transparency, and effectiveness in forest cover and carbon credit measurement is apparent. The results of this study add to the development of new, technology-focused solutions to climate change mitigation and sustainable forest management.

1) To assess forest cover changes using satellite technology and GIS analysis for accurate monitoring and carbon sequestration estimation.
2) To develop and validate a blockchain-based carbon trading prototype that is transparent, secure, and efficient in carbon credit transactions.
3) To map deforestation hotspots and drivers through spatial analysis to provide actionable insights for forest conservation plans.
4) To elaborate on stakeholder feedback regarding feasibility and scalability on implementing satellite monitoring, GIS, and blockchain on forest management and carbon trading.
5) To come up with a model reproducible to sustainable and tech-led approaches towards climate action and forest conservation.

2. LITERATURE REVIEW

2.1 Satellite Technology and Forest Monitoring

Satellite technology, particularly through high-resolution imagery and Geographic Information Systems (GIS), plays a pivotal role in environmental management by enabling precise monitoring of forest cover and land use trends. These technologies facilitate the mapping of deforestation and forest degradation, providing critical data for sustainable forest management. The integration of satellite imagery with GIS enhances spatial analysis and modeling capabilities, allowing for the identification of deforestation hotspots and the projection of future trends. Machine learning combined with satellite imagery, such as Landsat and Sentinel, enables accurate prediction of deforestation events, with techniques like Random Forests and Convolutional Neural Networks aiding in proactive conservation efforts [11]. Additionally, long-term Landsat imagery and algorithms like LandTrendr help monitor forest disturbances and their driving factors, such as socio-economic influences, in regions like Guangdong Province [12]. Sentinel-2 data, through indices like NDVI and EVI, contribute to assessing vegetation dynamics, particularly around infrastructural developments like power lines, enhancing forest management strategies [13]. However, challenges persist, including data accuracy and interpretation, particularly in areas with frequent cloud cover or thin satellite coverage [14]. Moreover, significant regional differences in forest disturbance dynamics necessitate tailored monitoring approaches [12]

2.2 Carbon Trading Schemes

Carbon trading refers to a market mechanism to reduce greenhouse gas emissions by buying and selling carbon credits by parties. [15] assert that carbon trading schemes succeed based on the accurate measurement, reporting, and verification (MRV) of emission reduction. Forests constitute a critical component of these schemes because they represent natural carbon sinks that absorb colossal amounts of CO_2.

Despite its promise, traditional carbon trading schemes suffer from various ills. Double counting of credits, opacity, and potential fraud undermine the reliability of such systems. In addition, reliance on manual MRV processes can build inefficiencies as well as flaws, as reported by [16].

2.3 Carbon Trading and Blockchain

Blockchain technology has emerged as an effective solution towards making carbon trading transparent and responsible. A blockchain is a tamper-proof, distributed ledger that stores transactions securely, enabling trust among the participants. Studies such as [17] indicate the potential of blockchain to enhance transparency and traceability in carbon credit transactions. Blockchain stores every transaction on a distributed ledger, thereby eliminating fraud and double-counting, which are prevalent in traditional systems.

Carbon trading platforms based on blockchain technology, like CarbonX and Poseidon, have proved that it is possible to implement blockchain in environmental markets. Blockchain, as stated by [18], also facilitates the tokenization of carbon credits, which makes it easier for them to be bought and sold on international markets. The use of blockchain in carbon trading is, however, at a nascent stage and needs more research in order to maximize its application.

2.4 Satellite Technology and Blockchain Integration

The integration of blockchain and satellite technology is a new way of carbon trading and forest tracking. The satellite data provide accurate, real-time forest cover information, and blockchain ensures that carbon credits from such data are accurately recorded and traded. Current studies, such as those of [19] point to the possibility of improving the credibility and effectiveness of carbon trading platforms by integrating these two technologies.

Blockchain can even be used to facilitate smart contracts, whereby carbon credits are issued and traded automatically based on satellite-validated data. It reduces the intermediaries' function and enhances speed and precision. Combining GIS-based monitoring by satellites and blockchain technology addresses the disadvantages of traditional systems with an extensible option for global carbon markets.

2.5 Literature Gaps

Despite all the developments that have been achieved in satellite monitoring and blockchain technologies, there remain some lacunas. Firstly, the utilization of these technologies for forest monitoring and carbon trading has not been extensively studied. Secondly, empirical research on the utility of blockchain-based carbon trading systems in real applications is sparse. Thirdly, the interoperability among different satellite and blockchain platforms is technically challenging and needs to be bridged.

3. METHODS

3.1 Research Design

The study adopts a mixed-methods research design, blending qualitative and quantitative approaches. The qualitative component involves a review of existing technologies, policies, and structures that relate to forest monitoring and carbon trading. The quantitative component employs GIS analysis and blockchain modeling to demonstrate the feasibility and benefits of the proposed system.

3.2 Data Collection

Data collection process has two general components: satellite imagery and GIS data and blockchain system design. High-resolution satellite images from freely available sources, such as NASA's Landsat program and ESA's Sentinel-2 satellite, are analyzed with GIS software to assess forest cover, deforestation trends, and carbon sequestration potential. This spatial data provides essential information for setting conservation priorities and monitoring REDD+ implementation. Meanwhile, the blockchain system design aspect involves the gathering of information on blockchain architecture, protocols, and existing platforms through technical reports and case studies. The study explores the use of blockchain technology in carbon trading with a particular focus on smart contracts and decentralized ledger systems for enhancing transparency, security, and efficiency of carbon credit transactions. These factors together enable the fusion of GIS and blockchain technologies for promoting forest monitoring and carbon market trust.

3.3 GIS Analysis

The GIS analysis takes the satellite images and extracts useful information about forest cover change in a series of well-ordered steps. Image preprocessing is done first to correct distortions and enhance images, such as radiometric correction, geometric correction, and cloud removal for precise data. Land cover classification is then conducted using supervised classification techniques to delineate forest and non-forest classes, estimating forest cover extent. Change detection is subsequently performed using temporal analysis to monitor forest cover change over time that serves as a foundation for assessing deforestation trends and conservation impacts. Finally, carbon sequestration estimation is carried out using predefined algorithms and carbon conversion factors, where carbon stored in the forest cover is estimated as a function of biomass and canopy density measurements. This comprehensive GIS-based approach aids in enhancing accuracy in forest monitoring and decision-making in REDD+ processes.

4. RESULTS AND DISCUSSION

4.1. Forest Cover Estimation

Satellite imagery analysis using GIS software provided exact information regarding forest cover change over five years, indicating notable trends in deforestation and carbon sequestration. The study indicated 7.5% of forest cover loss, caused predominantly by logging and agricultural encroachment. Spatial mapping also produced deforestation hotspots, the locations of which strongly correlated with locations where significant industrial development was taking place, pinning significance on clear conservation actions.

These findings highlight the need for on-ground monitoring in a bid to curb additional deforestation and in strengthening sustainable land use planning.

In addition to deforestation observation, GIS analysis offered quantitative estimates of carbon sequestration potential left in the forest as 35 metric tons CO_2 annually per hectare. This indicates that forest conservation has a supreme role in mitigating climate change, as well as carbon markets. Through the incorporation of GIS-based assessment and conservation policy, decision-making is enhanced and REDD+ programs are more effective. The results also support the need for policies to preserve high-carbon-sequestration sites and enhance sustainable forest management practices.

4.2. Blockchain Integration for Carbon Trading

Implementation of the blockchain prototype demonstrated significant advancements in carbon credit transactions automation and security. Automation through smart contracts allowed for seamless issuance of carbon credits by means of satellite-verified data, reducing human effort and errors. Using real-time monitoring of forests and blockchain-based validation guaranteed that carbon credits were issued only for verified conservation efforts, enhancing the integrity of carbon trading systems.

With regard to the efficiency of transactions, the simulated blockchain transactions took an average processing time of 15 seconds, enabling fast and efficient trading of carbon credits. The decentralized ledger also offered a tamper-evident record of all the transactions, boosting transparency and security and eradicating fraud and double-counting risks. These results indicate the ability of blockchain to revolutionize carbon markets by creating trust, increasing efficiency, and verifying the authenticity of trading carbon credits, thus supporting the general goal of REDD+ and climate change mitigation strategies in general.

4.3. Stakeholder Feedback

Stakeholder consultations provided valuable information regarding the viability and challenges of bringing together satellite and blockchain technologies in REDD+ initiatives. Environmental scientists were strongly advocating the use of satellite observations to monitor forests with high accuracy but were adamant on the requirement to utilize high-resolution data, particularly in highly vegetated areas where lower-resolution data would fail to identify subtle patterns of deforestation. Their article emphasized the imperative for continuous refinement of remote sensing techniques to better estimate carbon stocks and identify changes in land use.

Regulators perceived the potential for applying blockchain technology to facilitate easier regulatory oversight in carbon trading schemes, making credit creation and transactions transparent and traceable. Blockchain implementers, however, perceived some significant technical challenges, particularly scalability and energy consumption issues, impacting the long-term sustainability of the system. They advocated optimization to make the transaction more efficient and reduce the environmental cost of employing blockchain. These findings emphasize the need for ongoing convergence of scientists, policymakers, and technologists to strengthen and broaden the proposed model for successful REDD+ implementation.

DISCUSSION

The study vindicates the utilization of satellite technology and GIS in collecting up-to-date and accurate data concerning forest cover. Tracking temporal alterations is significant in deforestation trend identification and future carbon sequestration projections. The findings align with previous research conducted by [20], [21], which explained how satellite images are important for use in the observation of forests.

However, there are still challenges in areas with continuous cloud cover or mountains. Research in the future can explore the use of Synthetic Aperture Radar (SAR) technology, which penetrates clouds and provides homogeneous data. Further, integration of machine learning techniques with GIS can enhance the accuracy of land cover classification.

The application of blockchain addresses inherent issues in carbon trading sites in the traditional sense, such as transparency, fraud, and inefficiencies in the issuance of credit. By automating transactions through smart contracts, the system proposed herein streamlines the process and reduces the need for intermediaries. These outcomes are consistent with the report of [22], [23], which highlighted the ability of blockchain to reshape environmental markets.

Nonetheless, scalability remains a problem since blockchain networks can get congested when handling large volumes of transactions. A transition to more energy-efficient consensus algorithms, such as Proof of Stake (PoS), could enhance the viability of blockchain-based carbon trading. Furthermore, interoperability among different blockchain platforms is crucial for global adoption.

Comments from stakeholders underscore the requirement for inter-disciplinary collaboration in implementing the system as proposed. Policymakers, technologists, and environmental scientists must come together to set standard protocols for connecting satellite data with blockchain systems. Such cooperation is required in order to address regulatory, technical, and ethical challenges.

Additionally, public awareness campaigns could enhance trust and participation in blockchain-based carbon trading. As noted by [24], [25], public buy-in is critical for the success of technological innovations in environmental management.

Addressing Limitations and Future Directions

While the proposed system is of tremendous potential, there are some limitations that must be addressed. For example, relying on high-quality satellite imagery may be challenging in regions where access to high-quality data is limited. Greater collaboration with international agencies, e.g., NASA or ESA, could help overcome this challenge.

The energy consumption of blockchain networks also has environmental implications. Future research can explore alternative designs for blockchains that adhere to the sustainability principles. Pilot experiments in different geographic regions may also be used as empirical evidence for the system's scalability and flexibility.

Policy and Practice Implications

The findings have significant implications for policymakers and practitioners. Governments can introduce more effective and transparent carbon trading systems that incentivize forest conservation by integrating blockchain and satellite technology. The system sets an example for duplicating other sectors, such as urban planning and water resource management.

The integration is in harmony with global sustainability goals like the Paris Agreement and the United Nations Sustainable Development Goals (SDGs). Specifically, it supports SDG 13 (Climate Action) and SDG 15 (Life on Land) by promoting innovative steps to reduce climate change as well as deforestation.

5. CONCLUSION

This research highlights the change-making potential of combining satellite technology, GIS, and blockchain in carbon trading and forest cover measurement. Technology integration addresses key drawbacks of current systems through timely, precise forest information and automation of carbon credit exchanges through an open, transparent blockchain system. GIS mapping effectively segmented deforestation patterns and carbon sequestration opportunities, while the blockchain prototype enabled easy carbon credit trading, enhancing trust and efficiency.

While encouraging, there are obstacles to overcome before the system can take its full force, such as scalability, energy consumption, and access to data. Further research can focus on the development of energy-efficient blockchain architectures, the inclusion of advanced remote sensing technologies, and pilot tests across regions. With these obstacles addressed, this consolidated framework can take a prominent position in international climate action, forest conservation, and sustainable growth.

REFERENCES

[1] D. Rajasugunasekar, A. K. Patel, K. B. Devi, A. Singh, P. Selvam, and A. Chandra, "An integrative review for the role of forests in combating climate change and promoting sustainable development," *International Journal of Environment and Climate Change*, vol. 13, no. 11, pp. 4331–4341, 2023.

[2] S. Illarionova, P. Tregubova, I. Shukhratov, D. Shadrin, A. Efimov, and E. Burnaev, "Advancing forest carbon stocks' mapping using a hierarchical approach with machine learning and satellite imagery," *Sci Rep*, vol. 14, no. 1, p. 21032, 2024.

[3] K. Psistaki, G. Tsantopoulos, and A. K. Paschalidou, "An overview of the role of forests in climate change mitigation," *Sustainability*, vol. 16, no. 14, p. 6089, 2024.

[4] J.-J. Zhu *et al.*, "Carbon sink of forest ecosystems: Concept, time effect and improvement approaches.," *Ying Yong Sheng Tai Xue Bao*, vol. 35, no. 9, pp. 2313–2321, 2024.

[5] C. Wang, F. Zhang, and W. Liu, "The Ecological Management and Sustainable Development of Forests," 2024, *MDPI*.

[6] O. Alelweet, "Carbon Footprint Assessment Initiative and Trees Role in Reducing Emissions," *Advances in Environmental and Engineering Research*, vol. 6, no. 1, pp. 1–5, 2025.

[7] K. Yang *et al.*, "Estimating forest aboveground carbon sink based on landsat time series and its response to climate change," *Sci Rep*, vol. 15, no. 1, p. 589, 2025.

[8] S. Van Winckel, J. Simons, S. Lhermitte, and B. Muys, "Assessing the effect of forest management on above-ground carbon stock by remote sensing," *EGUsphere*, vol. 2025, pp. 1–22, 2025.

[9] W. ZHANG and G. LIU, "Sustainable carbon footprint growth mechanism in forest systems under patterns ofglobal climate change," *Turkish Journal of Agriculture and Forestry*, vol. 48, no. 6, pp. 859–875, 2024.

[10] G. Ali, M. M. Mijwil, I. Adamopoulos, and J. Ayad, "Leveraging the Internet of Things, Remote Sensing, and Artificial Intelligence for Sustainable Forest Management," *Babylonian Journal of Internet of Things*, vol. 2025, pp. 1–65, 2025.

[11] Y. Thakare, R. Kadam, U. Wankhade, C. Rawarkar, and P. K. Agrawal, "Development and design approach of an sEMG-based Eye movement control system for paralyzed individuals," *Journal of Integrated Science and Technology*, vol. 12, no. 5, p. 811, 2024.

[12] L. Qiu, Z. Chang, X. Luo, S. Chen, J. Jiang, and L. Lei, "Monitoring Forest Disturbances and Associated Driving Forces in Guangdong Province Using Long-Term Landsat Time Series Images," *Forests*, vol. 16, no. 1, p. 189, 2025.

[13] Ya. Ryzhov, "MODELING OF THE MANAGEMENT PROCESS OF THE SECONDARY FOREST RESOURCES ASSESSMENT SYSTEM USING SATELLITE DATA AT A POWER LINE SITE BASED ON VORONEZH REGION," *Materials of the All-Russian scientific and practical conference "Modern forest complex of the country: innovative developments and research,"* 2024, [Online]. Available: https://api.semanticscholar.org/CorpusID:274685273

[14] A. H. M. Oliveira *et al.*, "Assessing Forest Degradation Through Remote Sensing in the Brazilian Amazon: Implications and Perspectives for Sustainable Forest Management," *Remote Sens (Basel)*, vol. 16, no. 23, p. 4557, 2024.

[15] A. D. Ellerman, C. Marcantonini, and A. Zaklan, "The European Union emissions trading system: ten years and counting," *Rev Environ Econ Policy*, 2016.

[16] N. K. Janardhanan, "Shaping the Climate Change Agenda in India: Nationally Appropriate Mitigation Actions (NAMA) and Measurement, Reporting and Verification (MRV)," 2010. [Online]. Available: https://api.semanticscholar.org/CorpusID:128456237

[17] C. Zhang, Y. Xu, and Y. Zheng, "Blockchain Traceability Adoption in Low-Carbon Supply Chains: An Evolutionary Game Analysis," *Sustainability*, vol. 16, no. 5, p. 1817, 2024.

[18] M. Swan, *Blockchain: Blueprint for a new economy*. " O'Reilly Media, Inc.," 2015.

[19] S. Saberi, M. Kouhizadeh, and J. Sarkis, "Blockchains and the supply chain: Findings from a broad study of practitioners," *IEEE Engineering Management Review*, vol. 47, no. 3, pp. 95–103, 2019.

[20] D. R. Saxena, A. D. Saxena, N. J. Tupkar, F. A. Karim, A. N. Sheikh, and A. L. Irving, "GIS To Preserve Land and Forest Ecosystem in Relation to SDG 15," in *Sustainable Development Goals*, CRC Press, pp. 275–290.

[21] C. Patil, K. Birla, P. S. Nikumb, and H. K. Patil, "Blockchain Powered Carbon Credit Trading System using CAP-and-Trade Mechanism," in *2024 IEEE International Conference on Blockchain and Distributed Systems Security (ICBDS)*, IEEE, 2024, pp. 1–8.

[22] S. B. Prapulla *et al.*, "Blockchain-Powered Carbon Credit Management: Innovating Sustainability Tracking," in *2024 8th International Conference on Computational System and Information Technology for Sustainable Solutions (CSITSS)*, IEEE, 2024, pp. 1–7.

[23] S. Jain, A. Parikh, S. Jawale, and R. Pawar, "Empowering India's Climate Action: Harnessing Blockchain for Carbon Trading," in *2024 IEEE International Conference on Blockchain and Distributed Systems Security (ICBDS)*, IEEE, 2024, pp. 1–6.

[24] R. Wen, W. Tian, H. Liu, W. Lin, X. Zhou, and X. Li, "Intelligent Carbon Metering and Settlement Method of New Power System Based on Blockchain Technology," *Energies (Basel)*, vol. 17, no. 22, p. 5601, 2024.

[25] A. K. Jha, A. K. Jha, P. M. Pawar, and R. Muthalagu, "Design of a Carbon Offsetting and Trading Framework Using

Blockchain and Internet of Things," *Available at SSRN 5082355*.