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Blockchain based Voluntary Carbon Market for Bangladesh

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Attestation

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Abstract

Bangladesh is identified among the countries most vulnerable to climate change, facing significant environmental threats, including deforestation, rising carbon emissions, and severe climate impacts. Despite the critical need to mitigate these environmental challenges, Bangladesh currently lacks a structured and efficient voluntary carbon credit market. This absence hinders the potential of businesses, organizations, and individuals from effectively offsetting their carbon footprints and participating in sustainable environmental practices. A transparent, secure, and regulated carbon credit trading platform is urgently required to encourage widespread adoption of sustainability initiatives. The primary objective of this project is to design and implement a decentralized blockchain-based marketplace specifically adapted for voluntary carbon credit trading in Bangladesh. The platform aims to provide a secure, transparent, and user-friendly environment for businesses and individuals to engage in carbon offsetting activities. Additional objectives include establishing a clear incentive model that encourages active participation and laying foundational frameworks for future integration with environmental regulatory bodies in Bangladesh. Leveraging blockchain technology, this project proposes a robust, decentralized infrastructure designed to significantly enhance transparency, immutability, and security within carbon credit trading. Smart contracts form the backbone of the platform, enabling automated and secure peer-to-peer transactions without intermediaries, thus reducing opportunities for fraud or mismanagement. The system includes an intuitive, web-based frontend interface built using Next.js, allowing seamless access for users wishing to buy, sell, or verify carbon credits. Furthermore, integrated data analytics functionalities provide comprehensive insights into carbon credit activities, enabling continuous monitoring, reporting, and informed decision-making. This project successfully developed a scalable prototype platform demonstrating how carbon credits can be transparently and efficiently traded in Bangladesh. Core functionalities of the Minimum Viable Product (MVP) include secure token issuance representing carbon credits, decentralized peer-to-peer trading, robust credit verification mechanisms, and transparent blockchain-based transaction logging. The platform incorporates wallet authentication using MetaMask, enhancing ease of use and security for participants. The established MVP clearly demonstrates the feasibility of blockchain-based carbon markets in Bangladesh and sets a foundational path towards regulatory compliance, structured governance, and the development of sustainability-driven incentive models. Overall, this initiative addresses critical gaps within Bangladesh's environmental landscape, offering a pioneering approach to voluntary carbon credit trading. The platform's decentralized nature ensures transparency, fosters trust among stakeholders, and establishes groundwork for seamless future integration with national and international environmental frameworks.

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1 Introduction

1.1 Background of the project

Bangladesh currently confronts severe environmental challenges, notably the alarming rise in carbon emissions and extensive deforestation. Rapid industrialization and urbanization have compounded these issues, making sustainable environmental practices an urgent necessity rather than an option. One promising mechanism to mitigate these environmental impacts is the implementation of voluntary carbon credit markets. Such markets motivate industries, organizations, and individuals to engage proactively in eco-friendly and sustainable initiatives by monetizing carbon reduction efforts. However, Bangladesh lacks a robust, transparent, and regulated framework necessary to support an effective voluntary carbon credit market. Traditional market mechanisms often suffer from opacity, mistrust, bureaucratic inefficiencies, and susceptibility to fraudulent practices, deterring potential participants and undermining environmental objectives. Blockchain technology presents itself as an innovative and practical solution to these inherent challenges. By providing an immutable, transparent, and decentralized ledger, blockchain significantly enhances the credibility, transparency, and efficiency of carbon credit trading. Its capability for automation via smart contracts also ensures streamlined verification and management processes, establishing a strong foundation for a sustainable carbon credit marketplace in Bangladesh.

1.2 Problem Statement

Bangladesh, despite being one of the nations most vulnerable to the effects of climate change, currently lacks a structured, reliable, and transparent voluntary carbon credit market. The absence of such a system presents a critical barrier to fostering widespread participation in sustainable environmental practices. Existing approaches to carbon offsetting are fragmented, relying on isolated initiatives or informal mechanisms that often lack standardized verification, clear accountability, or traceability. This fragmentation results in an opaque environment where the authenticity of carbon credits is difficult to verify, and the integrity of offsetting activities remains questionable.

Furthermore, traditional carbon credit mechanisms that do exist are often marred by bureaucratic inefficiencies, susceptibility to fraudulent activities, and high operational costs. The lack of a transparent, standardized trading platform discourages businesses, non-governmental organizations, and individual stakeholders from actively engaging in carbon offsetting initiatives. Without an accessible and trustworthy marketplace, the momentum toward achieving national and international environmental goals, including Bangladesh's commitments under the Paris Agreement, remains significantly hindered.

Compounding the issue is the limited technological infrastructure supporting the current systems. Manual processes, paper-based certifications, and centralized data management models leave carbon credit operations vulnerable to errors, manipulation, and

delays. These inefficiencies ultimately undermine public trust and the financial viability of voluntary carbon markets in the country.

In response to these challenges, there is an urgent need for an innovative solution that ensures security, transparency, and efficiency. Blockchain technology offers a promising approach to address these systemic flaws. By leveraging blockchain's decentralized, immutable ledger and smart contract automation, it is possible to establish a voluntary carbon credit trading platform that minimizes fraud, enhances accountability, and builds stakeholder trust.

Thus, this project aims to design and implement a blockchain-based voluntary carbon marketplace tailored specifically for the socio-economic and environmental context of Bangladesh. The proposed platform will serve as a secure, accessible, and verifiable environment for carbon credit issuance, trading, and retirement, thereby addressing the core structural deficiencies currently impeding the growth of voluntary carbon markets in the country.

1.3 Outcome of the project

The primary outcome of this project is the successful development of a blockchain-enabled platform for voluntary carbon credit management and trading, specifically designed for the socio-economic and environmental needs of Bangladesh. Through the design, implementation, and testing phases, a Minimum Viable Product (MVP) was achieved that demonstrates the core functionalities required for a decentralized, secure, and transparent carbon credit marketplace.

Key outcomes of the project include:

- **Blockchain-based Carbon Credit Issuance and Trading:** A fully operational smart contract system was developed and deployed on a blockchain test environment. The contracts enable secure issuance of tokenized carbon credits, ownership tracking, and transparent peer-to-peer trading.
- **Secure User Authentication and Wallet Integration:** The platform incorporates MetaMask wallet integration, allowing users to authenticate and interact with the blockchain securely. This ensures user identity validation without relying on traditional centralized authentication systems.
- **Interactive Web-based Dashboard:** A user-friendly frontend interface was built using Next.js and React. The dashboard enables users to register land plots, calculate carbon credits based on environmental data, and conduct carbon credit transactions in a simple, intuitive manner.
- **Transparent Transaction Logging:** All transactions are immutably recorded on the blockchain, providing traceability, verifiability, and transparency. This outcome significantly addresses the fraud and opacity challenges traditionally associated with carbon trading.
- **Prototype Validation:** Functional testing demonstrated that the platform reliably supports end-to-end flows, from land registration to carbon credit calculation, issuance, and transfer. Early user feedback indicated high usability and trust in the system's transparency.
- **Foundations for Future Expansion:** The project sets a strong foundation for future enhancements, including integration with environmental regulatory bodies,

off-chain storage solutions such as IPFS for document proofs, IoT device data integration for real-time monitoring, and expansion into regional and international carbon markets.

Overall, the project effectively addresses key challenges faced by traditional carbon credit markets in Bangladesh and demonstrates how blockchain technology can be leveraged to foster sustainable environmental practices in a transparent, secure, and efficient manner.

2 Literature Review

[6] The reviewed paper, *"Agriculture-Food Supply Chain Management Based on Blockchain and IoT: A Narrative on Enterprise Blockchain Interoperability"*, presents a comprehensive analysis of the potential of integrating blockchain and Internet of Things (IoT) technologies to address longstanding challenges in the agri-food supply chain. The authors highlight how blockchain enhances transparency, traceability, and data integrity across all stages from production to consumption, while IoT devices enable real-time data acquisition on food quality, storage, and environmental conditions. A key contribution is the introduction of the Agri-SCM-BIoT architecture, a multi-tiered blockchain framework designed to tackle issues of scalability, storage, interoperability, and cybersecurity inherent in current single-chain systems. The study systematically classifies cyber threats, outlines smart contract functionalities, and evaluates blockchain's role in food safety, waste reduction, and inventory management. Notably, it emphasizes the need for cross-chain communication and standards for blockchain interoperability in heterogeneous agricultural networks. This narrative advance both technical and strategic understanding, offering a forward-looking blueprint for building secure, efficient, and transparent agricultural supply chain ecosystems.

[7] The article *"Blockchain and the Carbon Credit Ecosystem: Sustainable Management of the Supply Chain"* by Basu, Deb, and Singh explores how blockchain technology can be harnessed to improve carbon emission tracking and carbon credit management within complex global supply chains. The authors highlight the growing pressure on businesses to comply with environmental regulations and satisfy the demands of eco-conscious consumers and investors. They propose a blockchain-based architecture that integrates Internet-of-Things (IoT) devices, smart contracts, and a central private ledger to ensure transparency, traceability, and accountability in carbon emissions reporting. By digitizing emission data and automating carbon credit generation, trading, and governance, the system addresses key challenges like data inconsistency, lack of standardization, and corruption in traditional carbon markets. The paper uses a bicycle manufacturing case study to illustrate how the architecture enhances carbon supply chain efficiency and facilitates impact investing. Ultimately, the study underscores that blockchain is not only a technological solution for sustainability but also a strategic tool for businesses navigating the transition toward environmentally responsible operations.

[11] The paper *"Distributed Off-Chain Storage of Patient Diagnostic Reports in Healthcare System Using IPFS and Blockchain"* proposes a privacy-preserving, scalable architecture to manage electronic medical records through a consortium blockchain integrated with the InterPlanetary File System (IPFS). The authors critique traditional centralized systems for their vulnerability to data breaches and reliance on third-party control, which compromise patient privacy. The proposed model offloads heavy diagnostic data to IPFS while storing only content-addressed hashes on-chain, thereby ensuring data integrity, immutability, and efficient retrieval without overburdening the blockchain. A proof-of-work consensus mechanism validates transactions, and access is controlled through proof-of-identity (PoI), allowing only authorized peers, such as doctors and hospitals, to partic-

ipate. Implemented in Python with Flask and IPFS 0.4.19, the system demonstrates performance efficiency in terms of upload, mining, and access time across varying report sizes. This hybrid framework advances the state of medical data management by merging blockchain's security with IPFS's distributed storage, offering a decentralized yet controlled alternative to conventional cloud-based healthcare systems.

[12] The paper *"A Survey of Blockchain Security Issues and Challenges"* by Iuon-Chang Lin and Tzu-Chun Liao provides a comprehensive overview of the core principles, applications, and vulnerabilities associated with blockchain technology. It begins by outlining the foundational components of blockchain—including decentralization, immutability, transparency, and cryptographic security—before categorizing blockchain into public, consortium, and private models based on access control and use-case requirements. The authors explore popular implementations like Bitcoin, Ethereum, and Hyperledger, and then delve into critical security concerns such as 51% attacks, double-spending, forks (both hard and soft), scalability issues, transaction latency, regulatory gaps, and the high integration cost of transitioning existing infrastructures to blockchain systems. The survey emphasizes that while blockchain has transformative potential across industries, especially in finance and supply chain, its vulnerabilities—particularly related to consensus mechanisms and network governance—must be addressed through continued research, standardization, and robust security protocols. The study serves as a foundational reference for understanding both the opportunities and risks in deploying blockchain technologies at scale.

[5] The paper looks at KlimaDAO, a DAO (Decentralized Autonomous Organization) with tokenized carbon credits for transparency and efficiency in voluntary carbon markets. It looks at KlimaDAO's processes, including its KLIMA token, its use of staking and bonding, and its governance model, and looks at trends in the marketplace, including its pricing and retirements of its tokens, and its capitalization, and sees high early activity, a dip, and then leveling off, indicative of concerns over maturing in the marketplace, participant retention, and uncertainty over regulators. In regard to DAOs' success with KlimaDAO in voluntary carbon markets, the paper sees a need for frameworks and standardization for regulators and long-term viability and effectiveness in off-setting greenhouse gas emissions.

[8] The article *"Smart Agriculture Assurance: IoT and Blockchain for Trusted Sustainable Produce"* presents a robust, integrated framework that combines blockchain technology with IoT systems to ensure sustainable agricultural practices and verifiable food certifications. Addressing critical challenges such as greenwashing, fraudulent food labeling, and unsustainable farming, the authors propose a blockchain-based solution that transparently tracks produce from farm to consumer through immutable smart contracts and real-time sensor data. The system supports multiple certifications, including Organic, Non-GMO, and Global GAP, by continuously monitoring soil health, crop conditions, and environmental factors using IoT sensors. A permissioned Ethereum blockchain is used for secure, accountable registration and traceability of stakeholders and events, with off-chain IPFS storage for large data. Consumers can verify produce authenticity via QR codes linked to blockchain records. The study not only details the system design, smart contract implementation, and security evaluation but also demonstrates its advantages in promoting trust, traceability, and sustainable food systems. It stands out from existing literature by offering fully implemented, testable architecture that is scalable and adaptable to diverse certification standards.

[4] The paper *"Green Blockchain – A Move Towards Sustainability"* by Yehia Ibrahim Alzoubi and Alok Mishra provides a thorough literature-based and empirical assessment of energy-efficient blockchain technologies that aim to mitigate the environmental im-

pact of traditional Proof-of-Work (PoW) systems. Highlighting the excessive energy consumption and carbon emissions of networks like Bitcoin and pre-Merge Ethereum, the study identifies 23 green blockchain platforms—such as Cardano, Tezos, Algorand, and Bitgreen—that use alternative consensus mechanisms like Proof-of-Stake (PoS), Proof-of-Space-Time (PoST), and Federated Byzantine Agreement (FBA) to achieve significantly lower emissions. In addition to evaluating the energy metrics and carbon footprints of these networks, the paper explores a range of green blockchain initiatives, including the Energy Web Foundation, SolarCoin, Crypto Climate Accord, and others that promote renewable energy adoption, carbon neutrality, and energy-efficient practices. The authors conclude that although green blockchain is in its early stages, it holds great promise for sustainable development across sectors like energy, finance, agriculture, and supply chain management. The study calls for improved regulations, greater transparency, enhanced energy forecasting, and deeper academic inquiry to scale these sustainable blockchain solutions globally.

[22] The paper *"Blockchain Technology in Carbon Trading Markets: Impacts, Benefits, and Challenges—A Case Study of the Shanghai Environment and Energy Exchange"* by Zhang, Chen, and Yue investigates the integration of blockchain in carbon trading systems, using empirical data from China's Shanghai Exchange. The authors employ an event study methodology to assess the short- and long-term impacts of blockchain implementation on carbon trading prices. Their findings reveal that blockchain significantly enhances transparency, security, and operational efficiency, leading to increased market confidence and a measurable rise in trading prices post-implementation. However, the study also identifies critical challenges, such as high energy consumption, increased costs, transaction delays, and technical complexity, which may hinder broader adoption. To address these, the authors suggest solutions like adopting Layer 2 protocols, selecting energy-efficient consensus mechanisms (e.g., PoS over PoW), and introducing regulatory innovations such as supervised "super nodes" to balance decentralization with accountability. The paper concludes by emphasizing blockchain's transformative potential for sustainable carbon markets, while advocating for refined frameworks, optimized technologies, and global collaboration to overcome its limitations and maximize long-term impact.

[9] The paper *"Global, Robust, and Comparable Digital Carbon Assets"* by Jaffer et al. introduces the PACT (Permanent Additional Carbon Tonne) carbon stablecoin as an innovative solution to long-standing issues in the voluntary carbon market (VCM), including credibility, inefficiency, illiquidity, and lack of comparability. The authors propose a data-driven framework that uses remote sensing, econometric modeling, and blockchain infrastructure—specifically the Tezos blockchain—to issue digital carbon assets with transparent, reproducible valuations based on additionality, leakage, and permanence. PACT tokens incorporate co-benefits such as biodiversity, social justice, and local livelihoods, which are tracked and categorized to allow for pool-based fungibility and buyer-specific filtering. The system enhances liquidity by enabling real-time, automated trading and offsetting via smart contracts while ensuring trust through a fully auditable, open-source computational pipeline. The paper contrasts PACT's approach with existing blockchain carbon credit platforms like Toucan and Flowcarbon, which suffer from incomparable baselines and risk of "junk credits." By integrating robust valuation techniques with smart governance, the PACT model presents a scalable and trustworthy digital infrastructure for managing carbon credits and driving impactful climate finance.

[24] The paper *"Harnessing Web3 on Carbon Offset Market for Sustainability: Framework and A Case Study"* by Zhou et al. explores how blockchain and Web3 technologies—augmented by wireless systems—can transform the voluntary carbon offset market for improved sustainability. The authors present a three-layered framework (physical, techno-

logical, and societal) demonstrating four core blockchain utilities: recording and tracking, wide verification, value trading, and concept dissemination. Using the Web3 platform Nori as a case study, the paper illustrates how blockchain-based carbon credit NFTs (NRTs) can overcome the limitations of traditional carbon markets—such as double-counting, poor transparency, and high entry barriers—through smart contracts, decentralized verification, and real-time monitoring via IoT and remote sensing. The study includes an in-depth analysis of buyer profiles, behavioral clustering, and econometric modeling to assess market influencers, revealing that public opinion plays a greater role than energy prices in Nori's dynamics. Additionally, a Twitter-based sentiment analysis underscores how NFT-backed offsets are gaining traction even amid broader crypto market downturns. Ultimately, the study concludes that Web3-native carbon offset platforms like Nori could lead the next wave of sustainability-driven blockchain innovation.

[1] The paper *"Enabling Carbon Credit Transparency: The Role of Fintech in Creating Traceable, Accessible Markets"* by Kelvin Lawrence White provides a comprehensive analysis of how financial technology (fintech) can revolutionize the carbon credit market by addressing its core challenges—transparency, traceability, and accessibility. The study emphasizes the transformative potential of technologies like blockchain, smart contracts, tokenization, and AI in combating fraud, double-counting, and exclusion in both voluntary and compliance carbon markets. Through fractionalized carbon credits and digital trading platforms, fintech democratizes access, enabling small businesses, individuals, and developing countries to participate in carbon offset initiatives. The paper also proposes a conceptual framework for integrating fintech into carbon credit systems, supported by case studies, surveys, and interviews. While highlighting significant benefits such as cost reduction, increased market liquidity, and automated verification, the author acknowledges challenges like regulatory fragmentation, data privacy, and the need for global standardization. Ultimately, the paper asserts that with collaborative governance and targeted policy support, fintech can catalyze a transparent, inclusive, and efficient global carbon credit ecosystem aligned with net-zero emission goals.

[2] The paper *"Application of Blockchain Technology in Carbon Trading Market: A Systematic Review"* by Abiodun, Nwulu, and Olukanmi presents a thorough examination of blockchain's potential to transform carbon trading systems plagued by centralization, inefficiency, and data manipulation. Using the PRISMA methodology, the authors analyze 32 peer-reviewed studies from 2015 to 2023 to evaluate blockchain's role in enhancing transparency, trust, decentralization, and operational efficiency in carbon markets. The study categorizes blockchain platforms, consensus mechanisms, and implementation strategies across various global case studies, including China's ETS and Japan's microgrid initiatives. Key benefits of blockchain integration include automated verification, increased market liquidity, reduced fraud, and improved inclusion of smaller players through tokenization and smart contracts. However, challenges such as regulatory fragmentation, scalability issues, data privacy concerns, and a lack of skilled professionals persist. The authors propose a multi-layered architecture for blockchain-based ETS systems and suggest innovative future research directions, such as personalized carbon markets, Layer 2 solutions, and legal standardization. Overall, the study offers a comprehensive roadmap for policymakers, technologists, and researchers seeking to modernize carbon trading through blockchain integration.

[23] The paper *"Blockchain Technology in Carbon Trading Markets: Impacts, Benefits, and Challenges—A Case Study of the Shanghai Environment and Energy Exchange"* by Zhang, Chen, and Yue delivers an empirical and theoretical analysis of blockchain's transformative potential in carbon trading. Utilizing an event study methodology with data from China's Shanghai Exchange, the authors demonstrate that blockchain signifi-

cantly enhances transparency, reduces transaction costs, and improves market efficiency—reflected in short-term and sustained increases in carbon trading prices following blockchain-related events. The paper explores blockchain's role in mitigating regulatory inefficiencies, managing carbon financial derivatives, and enabling cross-border cooperation. However, it also raises important concerns such as high energy consumption, transaction delays, a steep learning curve, and reduced accountability due to user anonymity. To address these, the authors propose adopting energy-efficient platforms, Layer 2 scaling solutions like zkSync, and introducing regulatory "super nodes" to balance decentralization with oversight. Ultimately, the study contributes valuable insights into blockchain's dual-edged role in carbon markets and underscores the need for scalable, inclusive, and regulation-friendly blockchain architectures for global climate governance.

[17] The paper *"Trading Carbon Credit Tokens on the Blockchain"* by Laurens Swinkels offers a pioneering empirical analysis of blockchain-based voluntary carbon credit trading via the AirCarbon Exchange (ACX), showcasing how financial innovation can support climate action. Covering the years 2021–2022, the study examines the minting, burning, trading, and pricing of tokenized carbon credits on a decentralized exchange designed to reduce intermediation and increase transparency in the voluntary carbon market. Out of 3.8 million tokenized tons of CO equivalents, 2.8 million were burned—representing retired credits—while $21.2 million in secondary market trades occurred, mostly concentrated in a few token types like CET and GNT. The study finds that prices of ACX tokens align closely with comparable off-chain voluntary carbon markets, validating the platform's market integration. However, Swinkels also highlights challenges such as limited liquidity, small user base, and persistent concerns about the quality and additionality of voluntary carbon credits. The paper contributes to the broader literature on asset tokenization and climate finance by demonstrating how blockchain can enhance transparency, reduce costs, and potentially improve market trust in environmental assets.

[15]The white paper "A Blockchain-based Carbon Credit Ecosystem" by Dr. Soheil Saraji and Dr. Mike Borowczak presents a visionary framework for revolutionizing global carbon markets through blockchain technology. Addressing critical shortcomings in current carbon trading systems—such as lack of transparency, double-counting, high transaction costs, and market fragmentation, the authors propose a decentralized ecosystem underpinned by smart contracts and tokenized carbon credits. Their system introduces clear minting and burning protocols, a multi-signature verification process involving certified validators, and an automated market maker (AMM) to facilitate real-time, intermediary-free trading of carbon tokens. Notably, the model integrates NFTs as certificates of carbon offsetting, enhancing accountability and user participation. The ecosystem is designed to be inclusive, supporting stakeholders such as carbon emitters, validators, NGOs, and individual consumers. By creating a seamless bridge between environmental compliance and financial innovation, the paper offers a robust, scalable, and transparent infrastructure capable of aligning global carbon markets with sustainability goals and fostering more effective climate action.

[3]The paper "A Systematic Review of Blockchain Technology Adoption Barriers and Enablers for Smart and Sustainable Agriculture" by Akella et al. presents a comprehensive examination of blockchain's role in revolutionizing the agriculture sector. Using the PRISMA methodology, the authors reviewed 26 peer-reviewed articles published between 2015 and 2022 to identify key enablers and barriers to blockchain adoption in smart and sustainable agriculture. The study highlights blockchain's potential to enhance food traceability, stakeholder trust, supply chain transparency, and data security through smart contracts and decentralized architectures. Notable enablers include stakeholder collaboration, improved ICT infrastructure, increased customer trust, and integration with IoT

and AI. However, adoption is hindered by several critical barriers, such as regulatory uncertainty, lack of global standards, high infrastructure costs, scalability challenges, and privacy concerns. The authors emphasize that while technical issues can often be mitigated through Blockchain-as-a-Service (BaaS) providers and interoperability frameworks, broader adoption requires global regulatory alignment, industry-wide best practices, and user education. This review offers essential guidance for policymakers, developers, and researchers aiming to implement blockchain technologies in agricultural value chains to foster sustainability and trust.

[19]The paper *"Blockchain-Driven Solutions for Carbon Credit Trading: A Decentralized Platform for SMEs"* by Yun-Cheng Tsai presents a practical and theory-backed solution to democratize access to carbon credit markets for small and medium-sized enterprises (SMEs), particularly in Taiwan. Using Ethereum smart contracts, the study develops a decentralized trading platform that reduces transaction costs, eliminates intermediaries, and enhances regulatory compliance with frameworks such as the Carbon Border Adjustment Mechanism (CBAM) and the U.S. Clean Competition Act (CCA). Anchored in the Diffusion of Innovations theory and transaction cost economics, the platform features ERC-721 tokenized carbon credits, automated compliance checks, and a user-friendly React.js interface. Through controlled experiments comparing blockchain and conventional platforms, the study demonstrates significant reductions in transaction time (57%) and cost (46%), alongside high user satisfaction measured via the Kano model. While the paper acknowledges challenges like regulatory adaptation and governance, it concludes that such decentralized solutions can empower SMEs, accelerate carbon neutrality efforts, and reshape global carbon trading dynamics.

[13]The paper *"Bringing Technological Transparency to Tenebrous Markets: The Case for Using Blockchain to Validate Carbon Credit Trading Markets"* by Gary E. Marchant, Zachary Cooper, and Philip J. Gough-Stone provides a compelling argument for integrating blockchain and smart contracts into carbon credit markets to combat persistent issues of double-counting, greenwashing, and lack of transparency. The authors detail how existing voluntary and regulatory carbon markets are plagued by fragmented registries, unverifiable offset claims, and limited enforceability of contractual obligations, especially in sectors like agriculture and forestry. They demonstrate how blockchain's immutable, traceable, and decentralized ledger can improve trust and accountability, particularly through the implementation of smart contracts that automatically retire or void carbon credits upon use or resale. Case studies such as Nori and the Universal Carbon token illustrate practical implementations of these technologies, while proposed federal legislation like the Growing Climate Solutions Act signals institutional support. The paper concludes that while blockchain is not a silver bullet for climate mitigation, its integration into carbon markets offers a promising path toward restoring credibility, efficiency, and public trust in global offset systems.

[21]The paper *"Carbon Credits and Environmental Impact Tracking: The Role of Blockchain in Supporting Efficient and Secure Carbon Credit Markets"* offers an extensive analysis of how blockchain technology can address persistent inefficiencies, fraud, and transparency issues in carbon credit markets. Authored by Yadav et al., the study identifies core challenges such as double counting, inconsistent international standards, and cumbersome administrative processes that hinder global carbon trading. Through case studies of platforms like IBM's blockchain with the Environmental Defense Fund and VeChain's real-time credit tracking system, the paper illustrates how blockchain—combined with smart contracts—can automate verification, reduce transaction costs by up to 30%, and enhance cross-border market access. It highlights the potential of blockchain to standardize credit validation, automate compliance, and integrate with emerging tech-

nologies such as IoT and AI for real-time emissions monitoring. Despite acknowledging obstacles such as scalability, energy consumption, and regulatory fragmentation, the authors assert that blockchain offers a transformative pathway for making carbon markets more inclusive, transparent, and effective in achieving climate goals. The research concludes by advocating for unified global standards and deeper tech-policy collaboration to fully realize blockchain's potential in climate finance.

[14]The paper *"Carbon Trading with Blockchain"* by Andreas Richardson and Jiahua Xu presents a forward-looking model for integrating blockchain into emissions trading systems (ETS), with a focus on enhancing the efficiency, transparency, and scalability of carbon markets. Using the EU ETS as a foundational case, the authors propose a permissioned blockchain system that supports the issuance, trading, and surrendering of carbon credits through tokenization and smart contracts. The model introduces dual tokens representing emissions and permits, and automates market functions—including verification, allocation, and pricing—via on-chain logic and a Bancor-style liquidity mechanism. The paper emphasizes blockchain's potential to address key limitations in traditional ETS: high transaction costs, limited geographical reach, lack of inter-system linkage, and opacity in trading. However, it also acknowledges significant implementation challenges, such as regulatory dependence, data integrity, governance trust, and technological scalability. By proposing a hybrid approach that maintains trusted authorities while transitioning toward decentralization, the authors offer a pragmatic pathway for blockchain-enhanced ETS deployment. This work contributes a technically detailed and policy-relevant blueprint for future carbon market modernization.

[20]The paper *"The Role of Blockchain Technology in Enhancing Carbon Credit Market Transparency"* by Kelvin Lawrence White provides a thorough analysis of how blockchain can resolve longstanding issues of fraud, double-counting, and inefficiency in the global carbon credit market. Emphasizing blockchain's core attributes—immutability, decentralization, transparency, and security—the study explains how this technology can create a tamper-proof, auditable record of carbon credit issuance, trade, and retirement. Smart contracts are highlighted as tools for automating transactions, reducing administrative costs, and improving market inclusivity, particularly for small businesses and developing economies. Through literature reviews, case studies, and comparative analyses, the paper demonstrates how blockchain enhances market trust, traceability, and efficiency. However, it also acknowledges key barriers such as regulatory uncertainty, technical integration challenges, and the absence of standardized carbon credit protocols across jurisdictions. Ultimately, the study calls for global collaboration between policymakers, technologists, and industry actors to develop harmonized frameworks that can support the scalable and trustworthy adoption of blockchain in environmental finance.

[10]The paper *"DCarbonX Decentralized Application: Carbon Market Case Study"* by Nida Khan and Tabrez Ahmad introduces DCarbonX, a blockchain-based decentralized application (dApp) designed to improve transparency, traceability, and accountability in carbon credit trading. The authors address key issues in environmental, social, and governance (ESG) markets—such as greenwashing, double-counting, and lack of verifiable impact—by leveraging NFTs and smart contracts on the Solana blockchain. DCarbonX creates an immutable and traceable marketplace where carbon credit certificates are tokenized and traded, with detailed audit trails and analytics accessible through a user-friendly interface. The platform supports both primary and secondary carbon markets and is aligned with global climate frameworks like COP26 and Article 6 of the Paris Agreement. The paper also emphasizes the application of this system in sustainable finance, including green sukuk, and discusses broader implications for Islamic finance, DeFi, and embedded finance. Despite outlining several challenges—like limited developer exper-

tise, high capital requirements, and integration barriers—the study demonstrates how blockchain-based dApps like DCarbonX can offer scalable, secure, and inclusive solutions to meet carbon neutrality goals.

[16]The paper *"Efficient ML Technique in Blockchain-Based Solution in Carbon Credit for Mitigating Greenwashing"* by Bama Raja Segaran et al. presents a comprehensive review of how integrating machine learning (ML) with blockchain technology can enhance the transparency and credibility of forest-based carbon credit markets. The study highlights the widespread issue of greenwashing—where organizations falsely represent their environmental impact—and positions blockchain as a secure, immutable ledger that ensures traceability of carbon credits. However, the authors argue that blockchain alone cannot provide real-time fraud detection. They propose supplementing it with ML algorithms such as Random Forest, XGBoost, and Neural Networks, which can analyze large datasets (e.g., satellite imagery, disclosures) to identify anomalies and fraudulent claims. The paper evaluates these algorithms based on metrics like accuracy, precision, and scalability, concluding that XGBoost offers the best performance for real-time fraud detection. Additionally, the integration of satellite data is emphasized as crucial for accurate carbon sequestration monitoring. Despite its promise, the paper acknowledges challenges including data quality, algorithmic biases, regulatory fragmentation, and blockchain energy consumption. Ultimately, the review advocates for hybrid ML-blockchain models, robust regulatory frameworks, and standardization to build a credible, automated carbon credit verification ecosystem aligned with global climate goals.

[18]The chapter *"Sustainable Agriculture: The Role of Blockchain Technology in Ensuring Food Security"* by Tiyndel et al. explores how blockchain can revolutionize the agricultural sector by enhancing transparency, traceability, and efficiency across food systems. The authors identify four core areas where blockchain has transformative potential: intelligent farming, food supply chain management, agricultural insurance, and agriproduct transactions. By integrating with IoT and smart contracts, blockchain enables real-time monitoring of crop conditions, seed quality, and supply chain events—helping prevent fraud, reduce inefficiencies, and improve food safety. In agricultural insurance, the chapter emphasizes blockchain's ability to enable smart index-based insurance solutions that automate payouts using weather or crop data, reducing the limitations of traditional indemnity models. The authors also discuss how blockchain reduces transaction costs, empowers farmers with better market access, and promotes ethical food sourcing through traceable records. Despite these benefits, the paper acknowledges barriers such as high data integration costs, lack of incentives for smallholder participation, and interoperability issues with legacy systems. Overall, this work highlights blockchain as a foundational technology for achieving global food security and sustainable agricultural development.

3 Technical Design and Implementation

3.1 Technology Stack

This project utilizes a comprehensive technology stack designed to support a robust and scalable blockchain-based carbon credit marketplace. The core blockchain infrastructure relies on **Ethereum**, chosen for its widespread adoption, smart contract capabilities, and active developer ecosystem. Ethereum smart contracts are written in **Solidity**, compiled and deployed using **Truffle**, with local blockchain simulations conducted via **Ganache**. For the user-facing components, the frontend employs a combination of **Next.js** and **React**, integrated seamlessly with the Ethereum blockchain using **Ethers.js** for efficient wallet management and blockchain interaction. While this project primarily utilizes Ethereum, the architecture remains modular and adaptable for potential integration with other blockchain platforms such as Hyperledger in future expansions. The backend services, particularly for data processing and analytics, can be extended using **Node.js** or Python-based applications, ensuring flexibility and scalability for more complex future requirements.

3.2 System Components

The system architecture comprises three primary components designed to deliver a streamlined user experience, secure transactions, and a reliable registry system:

1. User Interface Dashboard:

The frontend dashboard provides a user-friendly interface that allows businesses, traders, and regulators to interact seamlessly with the carbon credit marketplace. Built with Next.js and React, the dashboard enables intuitive navigation, responsive design, and real-time updates. It supports secure wallet authentication via MetaMask, enabling transparent and secure blockchain interactions, including buying, selling, transferring, and verifying carbon credits. Additionally, users can monitor their carbon credit balance, transaction histories, and verification statuses through the intuitive graphical interface.

2. Smart Contracts:

The heart of the decentralized marketplace lies in Ethereum-based smart contracts. These smart contracts automate essential processes, including:

- **Carbon Credit Issuance:** Automatically generates and issues blockchain-based carbon tokens representing verified carbon offsets or reductions.
- **Transaction Management:** Handles secure and transparent peer-to-peer trading of carbon credits, ensuring immutability and transparency of transactions.

- **Verification and Authentication:** Provides cryptographic validation of credit ownership and transaction authenticity, significantly reducing potential fraud and disputes.

- **Incentive Mechanisms:** Enables the automatic distribution of rewards and incentives, motivating participants to engage proactively in sustainability activities.

These smart contracts are developed in Solidity and thoroughly tested in a local blockchain environment using Ganache and Truffle, ensuring robust performance and reliability.

3. Carbon Credit Registry:

A secure and immutable registry system maintains a comprehensive record of all issued carbon credits, including unique reference IDs, owner wallet addresses, and transaction histories. The registry ensures complete transparency and traceability of credits throughout their lifecycle, from issuance to retirement. It serves as a trusted source of truth for regulatory bodies, auditors, and market participants, significantly enhancing compliance and confidence in the platform.

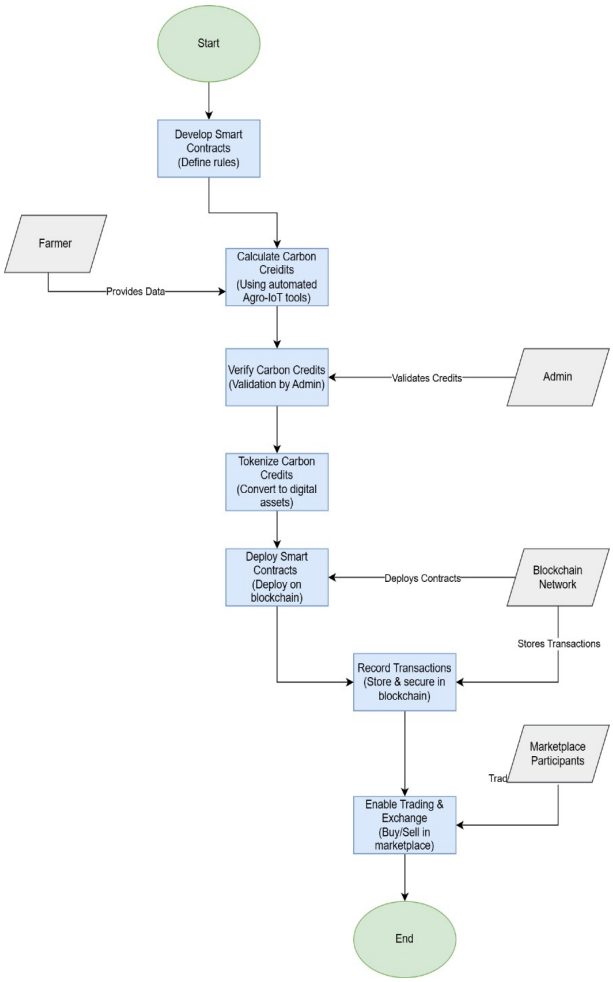

Figure 1: Flowchart for Voluntary Carbon Market

3.3 System Design Overview

The system design integrates blockchain technology seamlessly with a frontend application to deliver transparent, secure, and efficient carbon credit trading. Ethereum smart

contracts facilitate core functionalities such as token issuance, authentication, and marketplace transactions. Solidity contracts act as autonomous agents governing the issuance of carbon credit, transactions between participants, and maintenance of accurate ownership records.

The Next.js frontend leverages Ethers.js to bridge user interactions directly with blockchain transactions. Through secure MetaMask wallet authentication, users interact safely and conveniently with the blockchain, with the frontend providing real-time updates and feedback based on transaction outcomes. This responsive interaction enhances usability and ensures transparency for every action performed by users.

Furthermore, the carbon credit registry integrates seamlessly with smart contracts, ensuring accurate, immutable records of credit generation, ownership changes, and transaction histories. Every issued carbon credit is tied to a unique reference ID and corresponding wallet address, enabling complete traceability and auditability. This structured system architecture not only facilitates easy regulatory compliance but also lays a solid foundation for future expansion, including integration with IoT-based data collection and potential alignment with international carbon market standards.

3.4 Carbon Sequestration and Carbon Credit Calculation

As a tree matures, its capacity to sequester carbon increases, making older trees more efficient at absorbing CO_2. This relationship highlights the significance of forest conservation and the role mature trees play in mitigating climate change. By understanding and supporting these natural processes, we can enhance the capacity of forests to act as carbon sinks, thereby contributing to global efforts to balance our planet's carbon cycle and combat the escalating challenges of climate change.

To accurately determine the amount of CO_2 absorbed by trees, two critical measurements are taken directly from the tree: its diameter, measured in centimeters (cm), and its height, measured in meters (m).

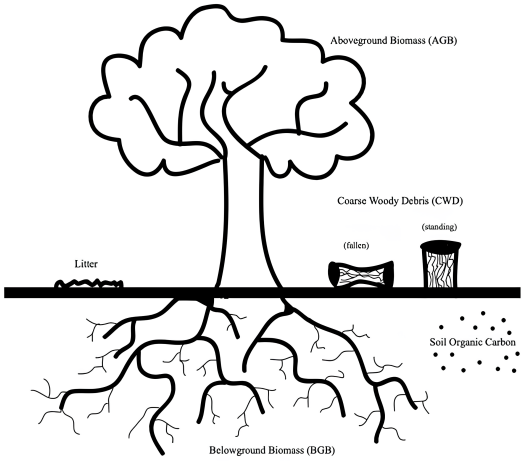

Figure 2: Flowchart for Voluntary Carbon Market

$$\boldsymbol{AGB = 0.25 \times D^2 \times H}$$

Where:

- AGB: Above-Ground Biomass (pounds).

- D: The tree diameter measured 1.37 meters from the ground (inches). This standard measurement provides better global consistency, although the formula can still be used if the tree is below 1.37 meters.

- H: The tree height (feet).

The overall green weight of the biomass is estimated to be 120% of the AGB value, based on the assumption that the Below-Ground Biomass (BGB), which comprises the tree's root system, accounts for approximately 20% of the AGB [**?**]. Therefore, BGB can be calculated as follows:

$$\boldsymbol{BGB = 0.2 \times AGB}$$

From these formulas, the total biomass (TB) from a tree is calculated as:

$$\boldsymbol{TB = AGB + BGB = AGB + 0.2 \times AGB = 1.2 \times AGB}$$

On average, a tree consists of 72.5% dry matter and 27.5% moisture content. To calculate the tree's dry weight (TDW), we multiply the total biomass by 72.5%:

$$\boldsymbol{TDW = TB \times 0.725}$$

Carbon typically occupies 50% of the total dry weight:

$$\boldsymbol{TC = TDW \times 0.5}$$

where TC stands for the Total Carbon content.

Using the value of Total Carbon (TC), the amount of CO_2 equivalent sequestered in a tree can be calculated. Since one molecule of CO_2 contains one atom of carbon and two atoms of oxygen, and given the atomic weights (C = 12u, O = 16u), the ratio of CO_2 to C is 44/12 = 3.67. Thus:

$$\boldsymbol{CO_2 \ weight = TC \times 3.67}$$

The overall carbon sequestration for a planted forest area can be calculated as:

$$\boldsymbol{CO_2 \ Sequestered = A \times (R/100) \times G \times C}$$

Where:

- A = Area of forest planted (hectares)

- R = Average tree survival rate (%)

- G = Growth rate of biomass (MT CO_2e/ha/year)

- C = Carbon sequestration factor (MT CO_2e/MT biomass)

Finally, the Carbon Credits Earned can be determined using the formula:

$$\boldsymbol{Carbon \ Credits \ Earned = Baseline \ Emissions - CO_2 \ Sequestered}$$

4 Implementation of the Proposed System

4.1 Algorithms for Blockchain-based Carbon Credit Verification and Trading

The platform employs specialized blockchain algorithms designed to facilitate secure, transparent, and efficient carbon credit verification and trading. Ethereum smart contracts form the core computational logic behind the issuance, verification, and peer-to-peer exchange of tokenized carbon credits.

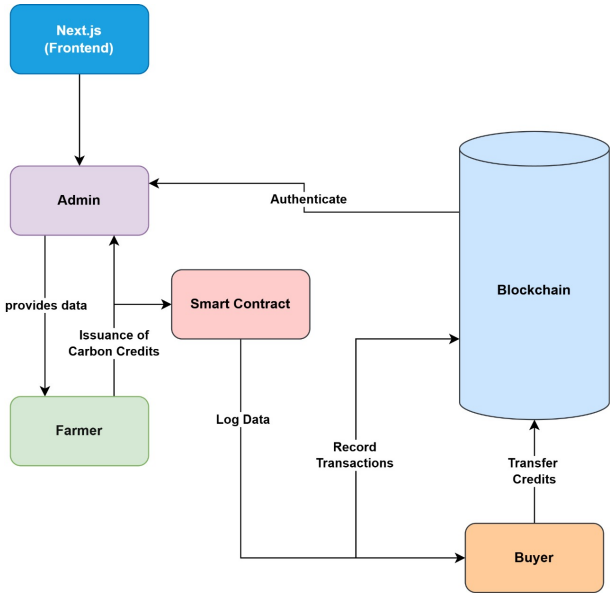

Figure 3: Flowchart for Voluntary Carbon Market

The key algorithmic processes include:

- **Carbon Credit Issuance Algorithm:**

  The issuance process is initiated by authorized administrators through a secure administrative interface. Upon receiving inputs such as carbon offset project details, emission reduction metrics, and verification data, the smart contract algorithmically calculates and generates equivalent blockchain-based carbon tokens, each associated with a unique reference ID and ownership record.

- **Carbon Credit Trading Algorithm:**

  Trading algorithms implemented through marketplace smart contracts securely facilitate buying and selling transactions. Upon buyer-seller agreement, the smart

contract autonomously executes transactions, transfers token ownership, updates ownership records immutably on the blockchain ledger, and ensures seamless token settlement, thus minimizing the risk of disputes or fraud.

- **Verification Algorithm:**

  Credit authenticity and ownership are verified through cryptographic wallet signatures and smart contract validations. Verification algorithms ensure each transaction and credit issuance meets predefined authenticity conditions, ensuring compliance and building trust within the marketplace.

4.2 Security Measures Implemented

Ensuring robust security was a primary concern throughout the implementation of the system. The platform integrates multiple advanced security protocols and methods:

- **Data Encryption:**

  Sensitive data transmitted and stored on-chain or through web interfaces utilize industry-standard encryption methods. Wallet interactions leverage cryptographic key-pairs, significantly reducing the risk of unauthorized data access or leakage.

- **Authentication:**

  User authentication relies on secure blockchain wallet integrations, specifically leveraging **MetaMask**, a widely used Ethereum wallet extension. Users authenticate via cryptographic signature methods, eliminating traditional password vulnerabilities. This approach offers enhanced security and streamlines user experience, reducing common authentication vulnerabilities.

- **Fraud Detection and Prevention:**

  Smart contracts incorporate logic to verify ownership, balance sufficiency, and legitimacy of transactions, effectively reducing fraudulent or invalid transactions. All interactions are logged immutably on the blockchain ledger, providing auditability and transparency, and ensuring malicious activities are swiftly detectable and traceable.

4.3 Prototype Demonstration and Functionalities

A comprehensive working prototype was successfully developed and deployed to showcase the platform's primary features and operational capabilities. The prototype is implemented using the Ganache local blockchain environment, providing an isolated and realistic testing ground that closely simulates Ethereum's mainnet behavior without associated costs or risks.

The demonstration includes the following key functionalities:

- **Authentication and User Login:**

  Users log into the platform via the **MetaMask** browser extension. This authentication mechanism provides secure, seamless wallet integration, allowing immediate participation in blockchain transactions. Each user's wallet address serves as their unique identifier within the system, securely managing identity and transaction history.

- **Carbon Credit Issuance via Admin Dashboard:**

  Administrators manage the issuance of carbon credits through a dedicated admin interface. After securely logging in, administrators input relevant carbon credit data, triggering a smart contract that generates and records tokenized carbon credits onto the blockchain. Each credit is uniquely identifiable, ensuring precise tracking and accountability.

- **Marketplace Trading Functionality:**

  Users interact directly with a decentralized marketplace implemented via smart contracts, enabling secure and transparent buying and selling of carbon credits. Smart contracts automate transactions, verify buyer-seller balances, transfer tokens, and update the blockchain ledger, accordingly, thus simplifying trade interactions and minimizing administrative overhead.

- **Frontend and User Experience:**

  A functional and responsive frontend built using **Next.js** and integrated with **Ethers.js** provides intuitive interaction, displaying critical real-time data, such as token balances, transaction statuses, and marketplace listings. This ensures an accessible, seamless, and user-friendly interface for all stakeholders involved.

The prototype demonstrates full end-to-end functionality—from wallet authentication, credit issuance, and verification to secure marketplace trading. It lays a robust foundation for scaling the platform to more complex, real-world deployments, potentially integrating with IoT data streams and regional or international carbon markets.

5 Conclusion and Future Works

5.1 Conclusion

This project successfully introduces a decentralized blockchain-based carbon credit trading platform tailored specifically for Bangladesh, effectively addressing existing gaps in the country's voluntary carbon market infrastructure. Leveraging blockchain's inherent transparency and smart contract automation, the developed platform provides secure and reliable mechanisms for carbon credit issuance, verification, trading, and incentivization. Through an intuitive and accessible user interface built using Next.js and integrated wallet functionalities via MetaMask, the system ensures seamless interaction for businesses, individuals, and regulatory entities alike. Overall, the project establishes a strong foundational infrastructure that encourages sustainable environmental practices, fosters trust among stakeholders, and promotes broader adoption of green initiatives.

5.2 Evaluation and Future Enhancements

The MVP effectively met the project's core objectives, providing transparent on-chain transaction traceability, robust wallet-based authentication, and functional carbon trading logic. However, several areas for enhancement were identified to optimize and scale the solution effectively. Future developments should emphasize decentralizing validation processes to ensure greater platform resilience and scalability. Optimizing smart contracts to reduce Ethereum gas costs will make participation economically accessible to a broader user base. Additionally, enhancing the platform's accessibility and user interface based on detailed user feedback will foster broader engagement and usability. The developed prototype underwent systematic evaluation to assess functionality, performance, user experience, and security aspects comprehensively.

5.2.1 Functional Testing

Functional testing was meticulously conducted on all core system components and key workflows. These included land registration, carbon credit calculation, token issuance, trading, and token transfers. Each functionality was tested individually and in integrated scenarios, confirming smooth interactions between smart contracts, frontend components, and blockchain records. Results showed consistent accuracy in data handling, reliable transaction execution, and successful state updates across all tested features.

5.2.2 Gas Fee Analysis

An extensive cost analysis was performed to evaluate the gas fees incurred across different smart contract interactions, such as land registration, carbon credit calculations, token

issuance, transfers, and marketplace transactions. Results indicated predictable and acceptable transaction costs within Ethereum's standard testnet benchmarks. However, it was identified that optimizing the smart contract code further could significantly lower gas costs, thus making the platform more economically viable for broader adoption.

5.2.3 User Experience Assessment

Interface walkthroughs and usability tests were conducted through simulated scenarios involving target user groups, including farmers, traders, and administrative personnel. The participants interacted with the Next.js-based frontend, assessing the clarity of information presentation, ease of navigating the dashboard, wallet integration via MetaMask, and general responsiveness of the application. Feedback indicated high usability and intuitive interactions, though minor interface refinements were recommended, particularly around transaction status indicators and error messaging.

5.2.4 Security Analysis

Preliminary security assessments confirmed that the implemented smart contracts and frontend integrations operated as intended, with no evident vulnerabilities during the initial testing phase. Authentication via MetaMask and wallet signature-based methods provided robust protection against common web-based threats. Nevertheless, a comprehensive smart contract audit by third-party security experts remains essential before deploying the solution in a live environment, ensuring complete security validation and risk mitigation.

5.3 Future Work

5.3.1 Regulatory Integration with Bangladeshi Environmental Bodies

In future developments, our project aims to integrate comprehensively with Bangladesh's environmental regulatory authorities, such as the Department of Environment (DoE) and the Ministry of Environment, Forest and Climate Change. Collaborating closely with these institutions can enhance compliance with local environmental standards, improve transparency, and ensure seamless verification of carbon credit activities. Building structured dialogues and data-sharing protocols will help align blockchain-based carbon credit systems with existing regulatory frameworks, enabling smoother adoption and legitimacy within the national context.

5.3.2 IPFS for Document Proof and Off-chain Metadata

Future enhancements will include integrating InterPlanetary File System (IPFS) technology to securely store large-scale documentation, such as land ownership certificates, environmental impact assessments, and detailed metadata about registered land plots. IPFS offers decentralized, immutable storage, greatly reducing data management costs and providing robust security against tampering or data loss. Leveraging IPFS will further bolster transparency, traceability, and integrity of off-chain metadata critical for audits and validations within our blockchain-enabled carbon credit framework.

5.3.3 IoT Device Implementation and Data Collection

A significant area of future exploration involves deploying Internet of Things (IoT) devices for precise, real-time data collection from agricultural sites. These devices can measure critical variables such as tree growth rates, soil health, carbon sequestration rates, and climatic conditions. Real-time IoT data integration into our blockchain network will enhance accuracy and credibility of carbon credit calculations, reduce manual data-entry errors, and enable near-instantaneous updates to stakeholders, thus improving decision-making and operational efficiency.

5.3.4 Expansion into Regional and International Carbon Markets

Looking ahead, the project intends to expand beyond national boundaries to tap into regional and global carbon markets. Establishing interoperability with international carbon registries and compliance frameworks, such as the Voluntary Carbon Market (VCM) and the Clean Development Mechanism (CDM), will enable Bangladeshi farmers and stakeholders to access broader economic incentives. This expansion can amplify environmental benefits by attracting international investors, fostering cross-border collaborations, and significantly increasing the scope and scale of impact achieved by our carbon credit initiative.

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A Solidity Smart Contract

```
pragma solidity ^0.8.20;

contract AgroCarbonCredit {
    struct Plot {
        uint256 id;
        string location;
        address owner;
        uint256 carbonCredit;
        bool registered;
    }

    mapping(uint256 => Plot) public plots;
    mapping(address => uint256) public balances;
    address public admin;
    uint256 public plotCounter;

    event PlotRegistered(uint256 id, string location, address owner);
    event CarbonCreditsCalculated(uint256 id, uint256 credits);
    event Transfer(address indexed from, address indexed to, uint256 value);

    modifier onlyAdmin() {
        require(msg.sender == admin, "Only admin can perform this operation");
        _;
    }

    constructor() {
        admin = msg.sender;
        plotCounter = 0;
    }

    function registerLand(uint256 plotId, string memory location) public {
        require(!plots[plotId].registered, "Plot already registered");
        plots[plotId] = Plot(plotId, location, msg.sender, 0, true);
        plotCounter++;
        emit PlotRegistered(plotId, location, msg.sender);
    }

    function getPlotCount() public view returns (uint256) {
        return plotCounter;
    }
```

```
    function calculateCarbonCredit(
        uint256 plotId,
        uint256 A,
        uint256 R,
        uint256 G,
        uint256 C,
        uint256 baselineEmissions
    ) public onlyAdmin {
        require(plots[plotId].registered, "Plot not registered");

        uint256 denominator = A * R/100 * G * C * 367 / 100;

        uint256 credits = baselineEmissions - denominator;
        plots[plotId].carbonCredit = credits;
        balances[plots[plotId].owner] += credits;
        emit CarbonCreditsCalculated(plotId, credits);
    }

    function transfer(address to, uint256 credits) public returns (bool) {
        require(balances[msg.sender] >= credits, "Not enough credits");
        balances[msg.sender] -= credits;
        balances[to] += credits;
        emit Transfer(msg.sender, to, credits);
        return true;
    }

    function buyCredits(address from, uint256 credits) public payable {
        require(balances[from] >= credits, "Seller has insufficient credits");
        uint256 cost = credits * 0.01 ether;
        require(msg.value >= cost, "Insufficient Ether provided");
        balances[from] -= credits;
        balances[msg.sender] += credits;
        payable(from).transfer(cost);
        emit Transfer(from, msg.sender, credits);
    }
}
```

B User Guide

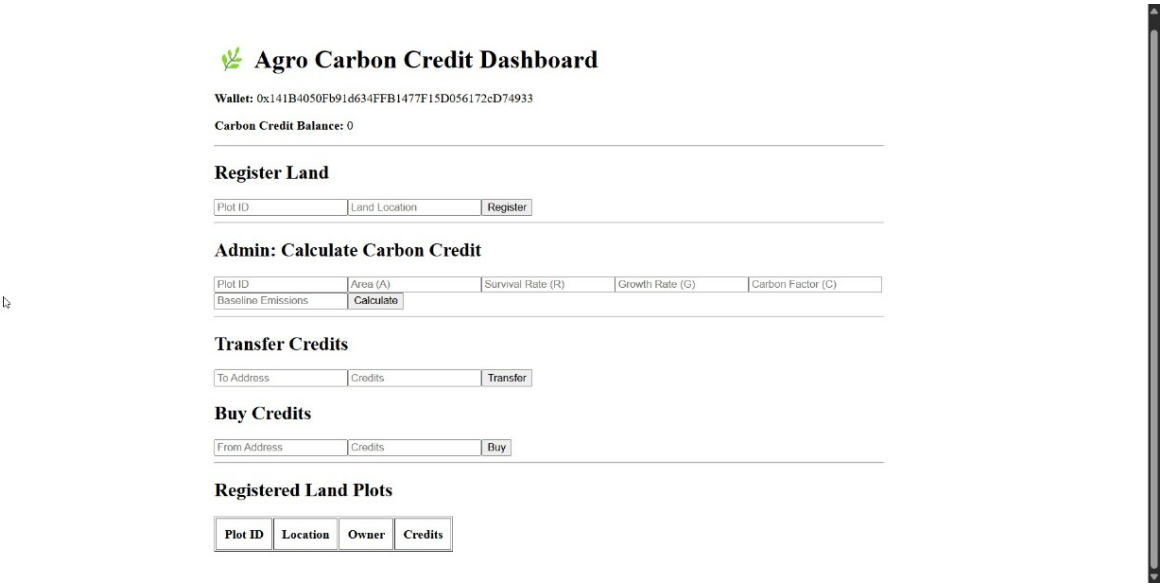

Figure 4: Flowchart for Voluntary Carbon Market

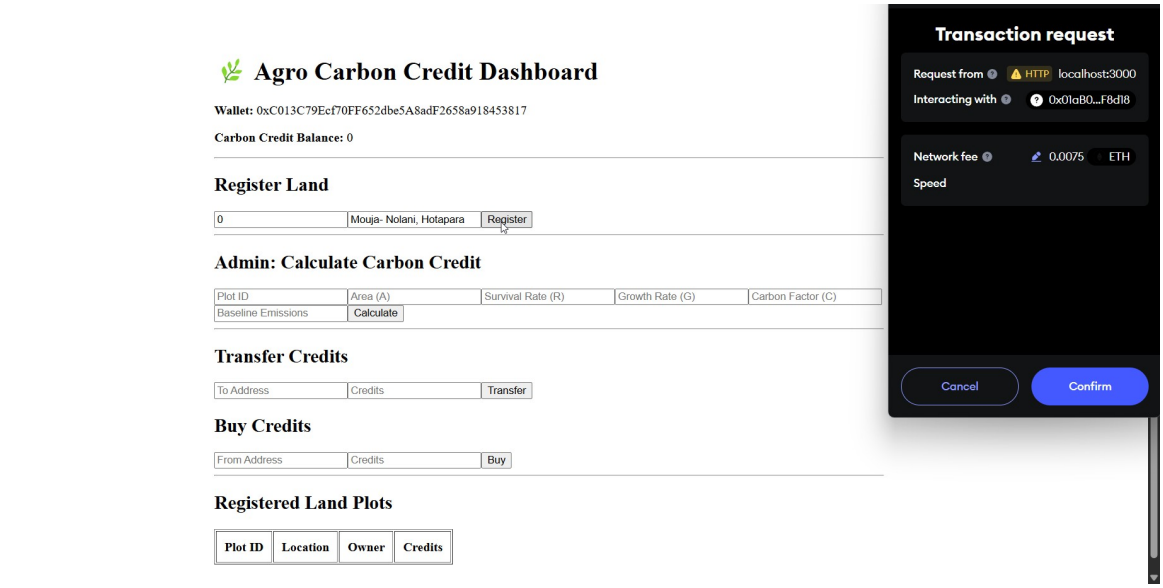

Figure 5: Flowchart for Voluntary Carbon Market

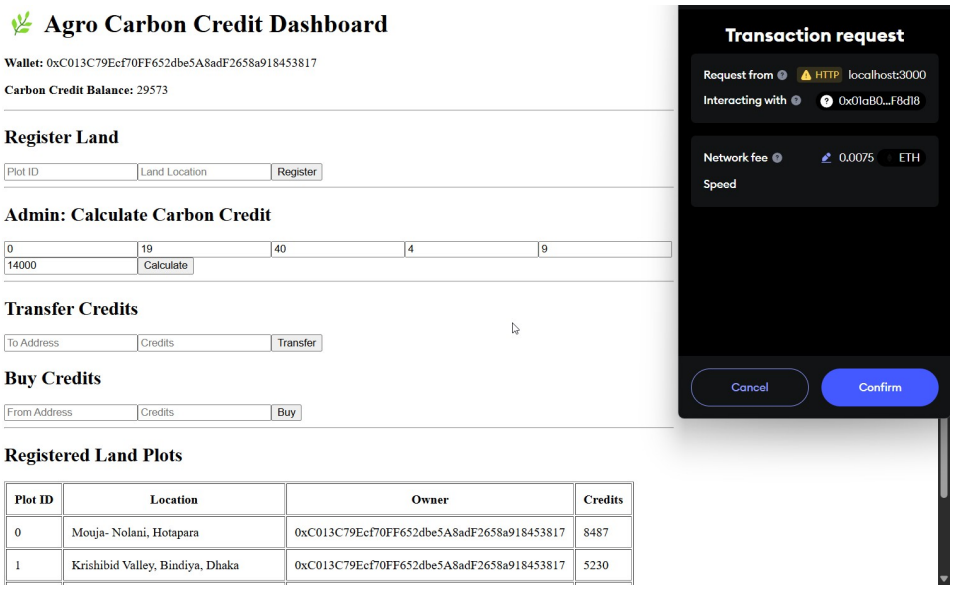

Figure 6: Flowchart for Voluntary Carbon Market

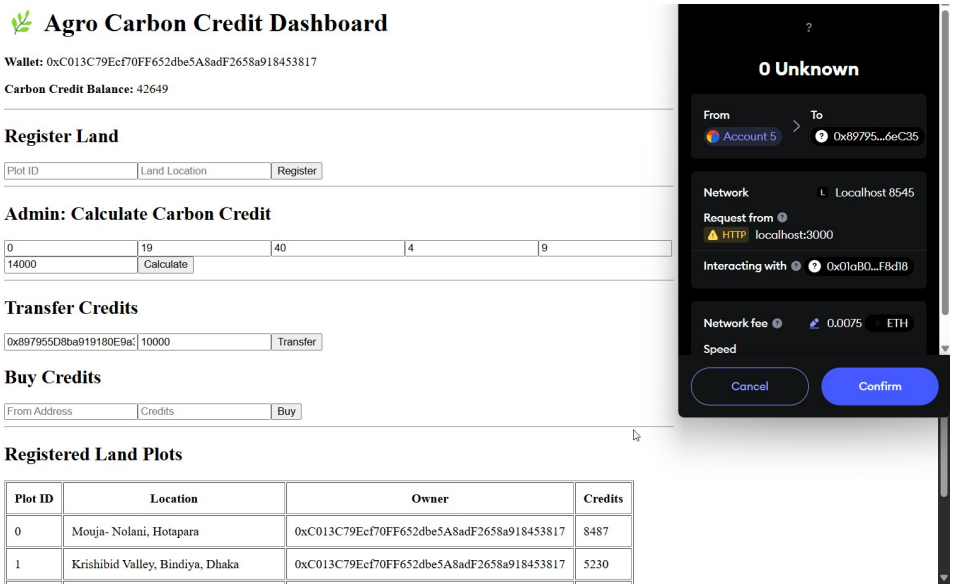

Figure 7: Flowchart for Voluntary Carbon Market

C Deployment Guide

```
>C:\Users\arafa\Downloads\Projects\AgroCarbonCreditProject_Final\MyTruffleProject> Tr

Compiling your contracts...
===========================

> Compiling .\contracts\AgroCarbonCredit.sol
> Artifacts written to | C:\Users\arafa\Downloads\Projects\AgroCarbonCreditProject_Fi

Compiled successfully using:
- solc: 0.8.20+commit.a1b79de6.Emscripten.clang

Starting migrations...
======================
> Network name: 'development'
> Network id: 5777+
> Block gas limit: 6721975 (0x6691b7)
2_deploy_contracts.js
=====================

Replacing 'AgroCarbonCredit'
----------------------------
> transaction hash: 0x2b760b0294fa0bb3d12abbacef7c86932ee2a927b91cd59cc8950a122c0eb0e
> Blocks: 0     Seconds: 0+
> contract address: 0x5ce52ff3406841dF096E37675614bAaf9AE33020
> block number: 1
> block timestamp: 1745435206
> account: 0xF81287b5E0dD34a0F36861Fd40F2EB5c33430723
> balance: 99.99534708325
> gas used: 1378642 (0x150952)
> gas price: 3.375 gwei
> value sent: 0 ETH
> total cost: 0.00465291675 ETH

Saving artifacts
-------------------------------------
> Total cost: 0.00465291675 ETH

Summary
=======
> Total deployments: 1
> Final cost: 0.00465291675 ETH
```