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A Comprehensive System for Sustainable Tree Plantation and Growth Monitoring using Blockchain, AI, and IoT

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Abstract: There are several environmental challenges faced by the world today, with deforestation and climate change being major threats to the environment and its sustainability. NGOs and Government bodies play a crucial role in addressing these issues by organizing and conducting tree plantation drives. However, a lack of transparency, mismanagement of funds, and inefficient tracking systems, have hindered the effectiveness of these efforts. Many problems occur after tree plantation as there is no record being held to track the growth of trees, funds transparency is not available, no overall analysis is provided for deciding which tree species should be planted in a particular area to achieve maximum sustainability and also to improve the chances of growth of trees. Only planting trees in large numbers won't help to solve this problem, a proper system is needed which can record time to time data regarding each and every tree through which we can help in the survival of all the trees and increase their lifespan. This will also help us in avoiding the drying and death of trees. The solution that we propose in this paper, to address the existing drawbacks is to create a web3 based platform to ensure the transparency of transferred funds and tree plantation by NGOs and government bodies, along with which we will implement a feature of tracking the status of planted trees using volunteers and IOT device in areas that aren't easily accessible by volunteers.

Keywords: *Growth detection, Secured using blockchain, Sustainability, Tracking volunteers, Transparency, Transparent plantation drives, Tree plantation analysis.*

1. Introduction

In the midst of the increasing global environmental challenges such as deforestation and climate change, collaborative efforts by Non-Governmental Organizations (NGOs) and Government Organizations to address these issues have become critical. Tree plantation drives, often organized as a response to these challenges, are a fundamental strategy for promoting sustainability and mitigating the impacts of climate change. However, despite their noble intentions, some important challenges remain, impeding the effectiveness of the tree plantation drives.

At present, challenges such as a lack of transparency, mismanagement of funds, and the lack of effective tracking methods have hindered the smooth implementation and monitoring of tree plantation drives. The traditional approach to the existing tree plantation initiatives frequently terminates with the act of planting trees, leaving a critical hole in the process's succeeding phases. Following the planting of the saplings, the lack of a comprehensive tracking mechanism, as well as insufficient transparency in fund allocation, pose substantial problems to the overall viability and longevity of these projects.

Recognizing these difficulties, this research paper aims to address them by incorporating modern technologies. We intend to transform the traditional method to tree plantation drives by utilizing Blockchain and Artificial Intelligence (AI). The system we propose incorporates an innovative approach for tracking the development and well-being of the planted trees, in addition to assuring transparency in financial transfers. This method entails the involvement of NGO volunteers or our Internet of Things (IoT) device, which is especially useful in areas where on-site monitoring is difficult because of accessibility.

Examining the current obstacles and their effects indicates that a paradigm shift is required. We envision a comprehensive system that provides real-time data on each planted tree in addition to the solemn act of tree planting. This data-driven strategy attempts to increase tree survival rates and overall longevity while lowering the risks of dryness and early death.

In this paper, we look at the challenges that existing tree plantation initiatives face, the potential of blockchain and AI to address these challenges, and the implementation of a robust system for transparent, accountable, and advanced tree plantation drives for environmental sustainability. Through the perspectives of sustainability, transparency, and growth tracking, this approach ensures that tree plantation efforts are not merely symbolic, but also supported by data-driven insights and technological advances.

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2. Related Work

Currently, plantation drives are conducted by NGO, Government organizations or private companies. These initiatives mainly rely on funding via crowdfunding or corporate sponsorships. Volunteers are then assigned to plant saplings at suitable locations for the execution of these plantation drives. Citizens can opt to donate to these drives either through direct contributions to NGOs or by participating in crowdfunding campaigns. Some platforms allow them to choose the type of tree they want to contribute to. These platforms provide a set of tree species along with their corresponding costs, enabling citizens to contribute towards the planting. In return, they usually receive a certificate acknowledging their specific contribution to environmental conservation. However, they do not provide a comprehensive overview of the planted trees' subsequent journey. The existing tree plantation system does not fully utilize advanced technologies and systems. Technological applications are confined to simple funding and awareness efforts rather than full solutions that solve the existing concerns.

The system [3] employs a Convolutional Neural Network (CNN) for detecting tree stems in forest videos. Ego-motion estimation is used to track stems during camera movement. The detection achieves 89% average precision (AP) with a Jaccard index of 0.5. Tracking maintains stem identity and position during occlusion and movement, achieving up to 49 fps. The limited dataset used in this paper hampers generalization across species. The algorithm does not classify different species and the tracking might confuse identities in dense forests.

The plant growth monitoring system mentioned in [4] starts by scanning a predestined area, generating a bit map using data from IR sensors. The control unit calculates plant dimensions, maximum height and width, storing this data in the microcontroller's database. The system also calculates stem diameter, environmental conditions (temperature and humidity), and compares current measurements with previous data. The collected information, including plant dimensions such as maximum height, width, and stem diameter and growth changes, environmental conditions, timestamp is displayed on an LCD and sent via SMS to a remote location. The proposed non-contact plant growth monitoring system utilizes infrared sensors to measure plant dimensions.

The research done in [5] used the Bellwether Phenotyping Platform, integrating a controlled environment and high-throughput imaging. The Plant-CV software facilitated non-destructive image analysis. Setaria species were grown under different water conditions. Data collection involved repeated image capture and trait analysis using Plant-CV. The study revealed distinct responses to water availability in wild and domesticated Setaria species. The dataset, consisting of around 79,000 images, is publicly available for querying yield-related phenotypes. The Bellwether Phenotyping Platform effectively combined automated growth and imaging for comprehensive analysis. The controlled-environment phenotyping may not fully capture field conditions. Along with that, non-destructive techniques might lack sensitivity for certain traits. Image processing methods mentioned here may require optimization for different species and conditions.

The paper [6] uses deep learning to detect plant growth events from time-lapse images. It captures seedling growth and focuses on transitions from cotyledon emergence to the first true leaf. Different CNN architectures are explored, including a baseline multi-class CNN and 2-Class CNNs for consecutive stage transitions. Implementing deep learning demands model expertise. Accurate models need ample annotated training data. Detection accuracy relies on image quality and the study focuses on specific events, not all growth stages.

In [8] air quality was measured at three sites in NIA by collecting air samples and determining the concentration of air pollutants using standard methods. Twenty tropical tree species common to the study area were chosen, and their air pollution tolerance levels were investigated using the Air Pollution Tolerance Index (APTI). The growth parameters of the selected tree species were recorded. The study was conducted in a single location, so the results may not be generalizable to other areas. The study was focused only on a limited number of tree species and it did not look at the long-term effects of air pollution on tree growth.

The framework proposed in [10] was evaluated using a hybrid qualitative approach and proved to improve the traceability of charity donations. The blockchain ledger allows for the tracking of donations from the moment they are made by the donor to the moment they reach the intended recipient. Transparency: All transactions are visible to all parties, which can help to build trust between donors, charities, and other stakeholders. This research also shows that the ledger is secure and tamper-proof, which can help to protect donations from fraud and theft.

The proposed system of [11] uses a decentralized consensus blockchain and IPFS-based data aggregation to effectively detect and classify DDoS attacks. The MHP-RF classifier is used to detect attacks. Once an attack is detected, the transaction information is stored securely in the blockchain. The transaction handling stage classifies the transaction type as normal or abnormal. The smart contract then appends the transaction to the blockchain. This system was evaluated in terms of accuracy, precision, recall, F-score, encryption time, decryption time, execution time, and space complexity. The results showed that the proposed system is effective in detecting and classifying DDoS attacks.

3. Drawbacks of the Existing Systems

The current system has some inherent flaws that limit the overall effectiveness of these activities. The following are important areas where the current system confronts challenges:

3.1. Financial Transparency

There is currently a lack of transparency in the allocation and utilization of funding for tree plantation drives. It is difficult to determine how money is dispersed and to ensure that it is used for its intended purpose. Donors and contributors lack a thorough awareness of the financial journey, raising concerns about the effect and efficiency of their contributions.

3.2. Tree Growth Tracking

Tracking tree growth accurately and precisely is a significant difficulty. There is currently no system in place that provides real-time updates on the growth and survival rates of individual saplings planted by volunteers during plantation drives. The lack of a solid tracking system makes it difficult to measure the impact of plantation efforts and determine the survival rates of planted trees, limiting the ability to make data-driven decisions for sustainable forestry. This makes determining the impact of the plantation drive on guaranteeing sustainable development challenging. Without proper tracking, understanding the longterm sustainability of the planted trees and the usefulness of the chosen species in contributing to environmental protection becomes difficult.

3.3. Data Analytics for Tree Species Selection

The absence of a solid data analytics framework affects strategic decision-making about which tree species should be planted in certain places to ensure optimal sustainability. In the absence of data-driven insights, tree species selection is frequently reliant on traditional traditions or general preferences rather than a thorough grasp of ecological conditions. Data analytics is essential for the effective execution of tree plantation drives because it provides significant insights into the environmental parameters that influence the growth and survival of various tree species. To find the best species for a specific place, advanced analytics can assess a variety of facts, including soil composition, climate conditions, and geographical factors.

3.4. Data Storage and Systematic Management

Since the existing system lacks systematic data storage and management, it is impossible to properly arrange and access critical information. To improve the platform's performance, a more structured data management method is required. The absence of a centralized and organized data storage system hinders the efficiency of data retrieval and analysis.

3.5. Geolocation Tracking

Tracking trees using geolocation data is tough because it is impossible to establish the exact location of each planted tree. Improving geolocation accuracy is critical for thorough monitoring. The current limitations in geolocation tracking compromise the ability to assess the spatial distribution of trees and their impact on specific areas.

Addressing these challenges requires a holistic and technologically advanced approach that integrates innovative solutions to ensure financial transparency, accurate tracking, community engagement, efficient data management, and informed decision-making.

4. Methodology

The methodology employed in this research paper revolves around a streamlined flow involving four key user roles: NGOs, Volunteers, Citizens, and Private Companies as shown in Fig 1. This collaborative ecosystem is supported by modules that cater to various functionalities, seamlessly integrating technological innovations and user engagement for sustainable environmental development.

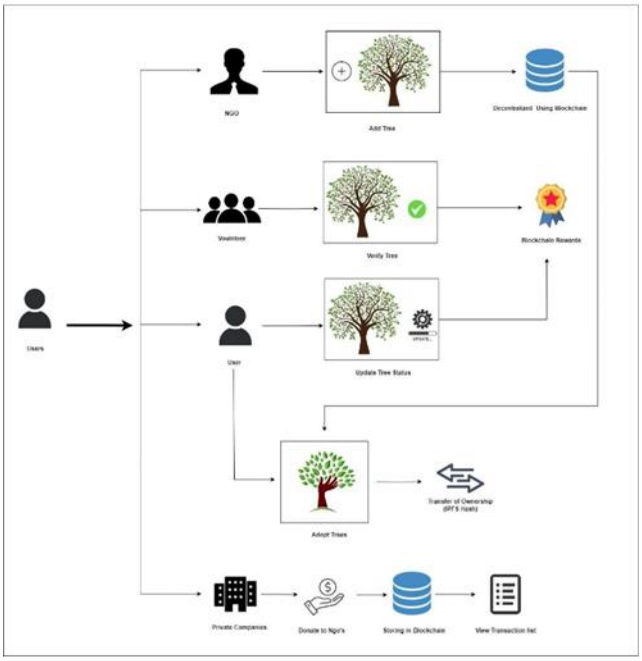


Fig. 1. Architecture Diagram of the system.

4.1. Tree Growth Detection using AI

This module is an essential component of our system, utilizing AI to detect and track the growth of the trees that have been planted by the NGOs. Volunteers take an active role in this process by taking pictures of the plants at frequent intervals, resulting in an important time-series dataset for data analysis. The integration of advanced computer vision libraries optimizes the accuracy and efficiency of growth detection.

The algorithm shown in Fig 2 uses AI to compare the current photos of the plants with their corresponding past images. This comparative analysis is critical in tracking and evaluating growth patterns. Notably, the use of computer vision involves elaborate masking techniques in which the plant is precisely segregated from the background in both the current and previous photographs. This thorough masking enables for a close investigation of the structural changes in the plant over time.

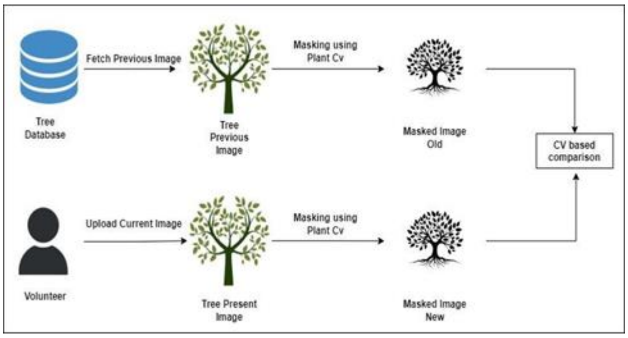


Fig. 2. Volunteer based Growth Tracking

The significance of this module lies in its ability to detect significant growth through establishing thresholds that, when crossed, indicate significant changes in the plant's development. The incorporation of AI, together with the capability of computer vision libraries, ensures a stable and dependable method for monitoring and verifying the growth of plants within the framework of the project.

4.2. Transparent Fund System and Donation using Blockchain

In the second major module, our goal is in creating a transparent funding system and facilitating donations using blockchain technology. Blockchain offers a secure, accountable, and transparent system for handling funds invested in tree plantation drives. Here we aim to address existing issues linked to financial transparency in traditional tree planting efforts by leveraging the potential of blockchain. Private companies who want to contribute towards these drives conducted by various NGOs can do so through our system.

Blockchain technology used in this module plays a crucial role in recording and validating each transaction. Every private company donation is securely registered on the blockchain, resulting in an immutable and transparent ledger of financial donations. This improves accountability while also establishing trust among stakeholders, ensuring that money is utilized effectively for the intended purpose of tree plantation initiatives. Our solution contributes to a more efficient and accountable financial ecosystem by adding blockchain into the contribution process, ultimately supporting the main goal of sustainable environmental development.

4.3. Tree Growth Monitoring using IOT

In the third module as shown in Fig 3, we delve into tree growth monitoring without the assistance of volunteers, targeting places that are difficult to reach for on-site volunteer visits. This module is critical in expanding the impact of our tree planting effort to distant forest areas where volunteer presence is limited. The implementation of IoT devices represents a significant advancement in our attempts to track and understand plant development in a variety of ecological environments.

These IoT devices are equipped with sensors that measure multiple aspects of plant growth. These devices give realtime data that improves our understanding of the development dynamics in tough environments by constantly monitoring critical factors such as plant height and environmental variables. Not only is the determined plant height updated in our central database, but also serves as a trigger for notifications, alerting relevant stakeholders when growth falls below predefined thresholds.

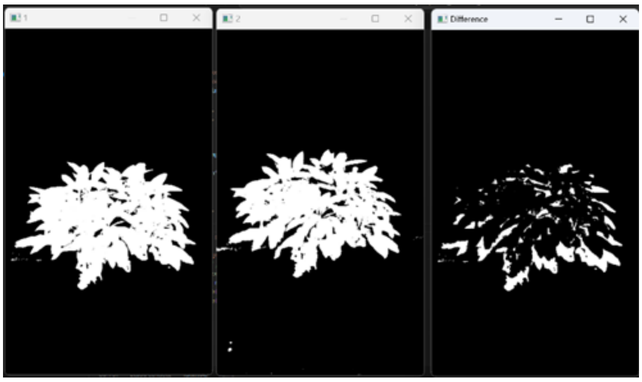


Fig. 3. Volunteer based Growth Tracking

This paper presents a seamless blend of user interaction and advanced technology, demonstrating our project as a catalyst for sustainable environmental development.

5. Implementation

Our system helps to ensure that the efforts put into the plantation drives effectively fulfil their promises and contribute meaningfully to sustainability of the environment.

To precisely track the growth of plants, the volunteer based tracking system uses computer vision technologies. This system utilizes time-series photos to assess whether significant growth has occurred compared to the previous image. Plant-CV is a library which is specialized in plant phenotyping. It is composed of various modular functions in order to be applicable to a variety of plant types and imaging systems. Our approach involves masking the plant and comparing the masked areas to precisely determine growth patterns. To validate the practical efficacy of this system, a collection of time-series images of plants was systematically amassed over a duration of five weeks.

The main process begins with NGOs adding the respective trees to the platform. This stage requires details of the tree, and the image of the tree is uploaded to the Inter-Planetary File System (IPFS), with the corresponding hash securely recorded on the blockchain. This not only guarantees the immutability of the tree data, but also creates a transparent and accountable record of each and every single tree added to the system.

Volunteers carefully examine the features of each tree added by the NGOs. A tree is only available for adoption after it has been verified by a volunteer. This comprehensive verification process ensures the tree database's dependability and legitimacy. Citizens can adopt trees once they have been verified. The transfer of ownership is done from the NGO to the adopting citizen via blockchain, creating a transparent and tamper-proof record of the adoption process.

6. Results

In this section, we give a complete study of the outcomes of our system's implementation. This section highlights our methodology's practical impact on our overall goal of supporting sustainable environmental development.

We make use of Plant-CV to precisely mask the plants from the collected images. We were able to determine growth patterns by comparing images of a given plant within our database as shown in Fig 4 using OpenCV, confirming the practical usefulness of the volunteer-based growth tracking method.

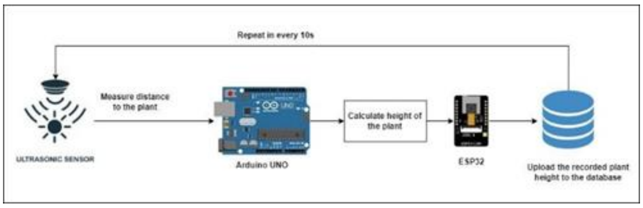


Fig. 4. Volunteer based Growth Tracking

Upon the successful adoption of a validated plant, transfer of ownership occurs, and the plant details are subsequently modified to reflect the new owner.

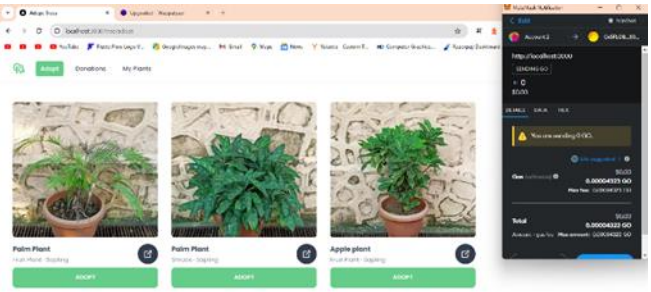
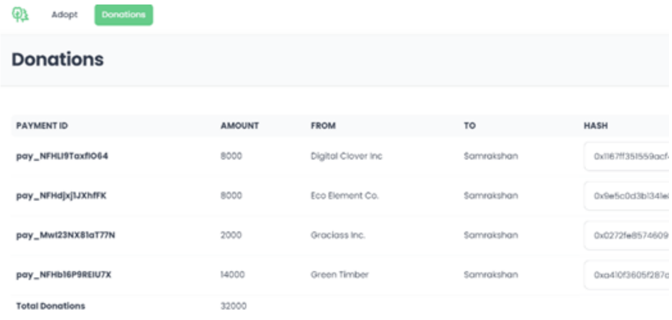


Fig.5. Volunteer based Growth Tracking

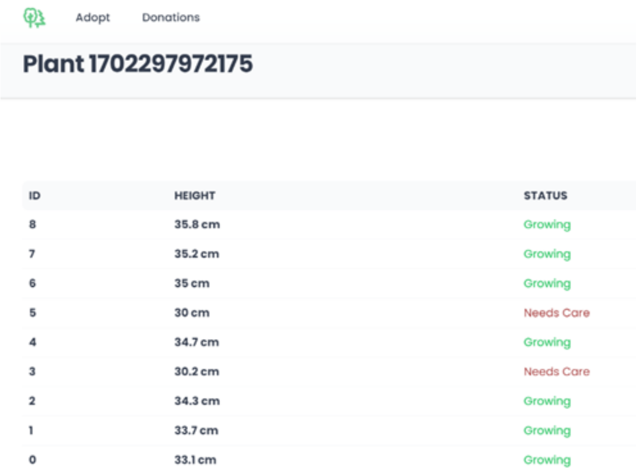
Private companies can donate funds via the donation page. This transaction is recorded on blockchain, and all donations received by a certain NGO are specifically shown to them on the page depicted in Fig 6.



PAYMENT ID	AMOUNT	FROM	TO	HASH
pay_NFHLl9Taxfl064	8000	Digital Clover Inc	Samrakshan	0x1167ff351559acf
pay_NFHdjxj1JXhfFK	8000	Eco Element Co.	Samrakshan	0x9e5c0d3b134le
pay_Mwl23NX8laT77N	2000	Graciass Inc.	Samrakshan	0x0272fe8574609
pay_NFHb16P9REIU7X	14000	Green Timber	Samrakshan	0xa410f3605f287c
Total Donations	32000			

Fig.6. Donation Details Page

The growth monitoring using IoT is shown in Fig 7. Users obtain insight into plant development as the sensor uploads plant height readings to the database on a regular basis. This real-time data enables users to monitor and analyze the development rate of each plant, promoting a better knowledge of the dynamic nature of the environmental contributions made possible by our device. The continual updates provide a comprehensive perspective of the plants' progress, providing users with vital data for informed decision-making and encouraging active participation in the sustainable growth path.



ID	HEIGHT	STATUS
8	35.8 cm	Growing
7	35.2 cm	Growing
6	35 cm	Growing
5	30 cm	Needs Care
4	34.7 cm	Growing
3	30.2 cm	Needs Care
2	34.3 cm	Growing
1	33.7 cm	Growing
0	33.1 cm	Growing

Fig.7. Readings from the IOT device

7. Conclusions and Future Work

In conclusion, our integrated approach to sustainable environmental development using advanced technologies and user interaction is a huge step forward in tackling the issues associated with traditional tree plantation drives. Our approach intends to improve transparency, accountability, and effectiveness across the whole lifecycle of tree planting projects by leveraging Blockchain, Artificial Intelligence, IOT and the active involvement of NGOs, volunteers, citizens, and private companies.

While our preliminary findings suggest promising advances in growth tracking and species selection, there is room for further work and improvement. One area for future research is to improve the computer vision algorithms used in volunteer based growth tracking to improve accuracy and accommodate different environmental circumstances. Furthermore, broadening the scope of data analytics to allow for more nuanced tree species selection, taking into account characteristics like biodiversity and ecosystem health, could lead to a more holistic and ecologically sound strategy.

Our project envisions a future in which tree plantation drives are more than just symbolic gestures, but also genuine contributions to a more sustainable and resilient environment.

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Author contributions

Monali Shetty: Conceptualization, Methodology, **Deon Gracias:** Software, Field study, **Ryan Valiaparambil:** Software, Writing-Original draft preparation, **Hisbaan Sayed:** Data curation, Writing-Editing, **Vijay Prajapati:** Hardware, Validation, **Mahek Intwala:** Data curation, Data analysis, **Prachi Patil:** Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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