TEAM
CARBONAUTS

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Blue carbon refers to the carbon stored in coastal ecosystems—mangroves, seagrasses, and salt marshes. These ecosystems absorb CO_2 efficiently, safeguard biodiversity, sustain coastal communities, and generate tradable carbon credits for climate mitigation. Despite this potential, India currently lacks a transparent system for blue carbon monitoring, tokenized credit generation, and community participation. Existing processes rely on manual verification, which is time-consuming, prone to fraud, and limits trust, efficiency, and equitable access to carbon markets. There is a need for a proactive model that leverages blockchain and digital MRV (Monitoring, Reporting, and Verification) to ensure transparency, efficiency, and inclusivity in blue carbon credit systems. Ultimately, this approach seeks to bridge the gap between coastal ecosystem services and carbon markets, unlocking climate, ecological, and community-level benefits while strengthening India's role in global climate action.

OBJECTIVES

- Developing India's first blockchain-based blue carbon registry to ensure transparency, trust, and efficiency in carbon credit markets.
- Using AI-powered anomaly detection to provide reliable validation and reduce fraud in monitoring, reporting, and verification (MRV).
- Enabling fractional carbon credit trading through tokenization, making carbon markets more inclusive and accessible.

DATASET DESCRIPTION

● BLUE CARBON ECOSYSTEM DATA

Includes mangroves, seagrasses, and salt marshes with parameters such as area, biomass, and carbon sequestration capacity. Data sourced from Sentinel-2, GEDI Lidar, SoilGrids, and drone imagery.

● GEOSPATIAL & SATELLITE INPUTS

High-resolution satellite datasets provide location-based parameters: vegetation index, land cover change, soil carbon, and tidal wetland mapping

● COMMUNITY & PROJECT DATA

NGOs, industries, and coastal panchayats provide on-ground monitoring data including plantation sites, restoration progress, and compliance records.

● GENERATED MRV DATA

IoT sensors, drones, and mobile apps generate real-time monitoring data for verification, anomaly detection, and automated reporting.

Problem :

India's coastal ecosystems—mangroves, seagrasses, and salt marshes—have immense potential for carbon sequestration, biodiversity conservation, and community resilience. However, the absence of a transparent, technology-driven, and inclusive Monitoring, Reporting, and Verification (MRV) system limits the ability to generate trusted blue carbon credits.

The current process is manual, fragmented, and prone to fraud, resulting in delays, low credibility, and reduced market access. Coastal communities and NGOs face barriers in participation due to limited digital literacy and a lack of incentives, while regulatory bottlenecks further slow approval cycles. Without a reliable system, India risks losing opportunities in the rapidly growing global carbon credit market.

Key Challenges & Mitigations

- Lack of transparent record-keeping → Mitigation: Blockchain registry for immutable project and monitoring records.
- Manual verification delays and fraud → Mitigation: AI/ML anomaly detection + automated validation to speed and secure verification (~95% accuracy target).
- Inconsistent or poor-quality data → Mitigation: Standardized data pipelines, automated pre-processing, and periodic re-validation with satellite + drone cross-checks.
- Low community participation / digital literacy → Mitigation: Multilingual mobile apps, incentive rewards, and targeted capacity-building (₹2 Cr initiative).
- Regulatory uncertainty & long approval cycles → Mitigation: Early collaboration with NCCR, BEE, and alignment with national CCTS for streamlined approvals.
- Scalability & data volume (satellite, IoT, drones) → Mitigation: Cloud-native infra + Layer-2 blockchain (e.g., Polygon) to support 10k+ users and large datasets.
- Sensor & integration costs → Mitigation: Hybrid approach — low-cost IoT for continuous monitoring + periodic high-res drone/satellite surveys; leverage grants/NGO partnerships.
- Market access and liquidity for credits → Mitigation: Fractional tokenization (ERC-20), marketplace UI, and buyer onboarding to increase demand and tradability.

Overview

A blockchain-based, AI-enabled Blue Carbon Registry and real-time MRV platform that digitizes project onboarding, automates verification/tokenization of credits, and enables a community-driven marketplace. Core goals: immutability of records, automated & accurate MRV, fractional token trading, and inclusive stakeholder participation.

Core Components

- Blockchain Registry & Tokenization — Immutable storage of restoration and monitoring records; smart contracts to automate carbon-credit tokenization (ERC-20) and enable fractional trading.
- Real-time MRV (Data Collection) — Integrated IoT sensors, drone imagery, mobile apps and satellite feeds (Sentinel-2 / Earth Engine) for continuous, geolocated monitoring.
- AI/ML Validation & Analytics — Automated preprocessing, anomaly detection, and AI models to compute carbon credits (high SOC / biomass metrics reported), improving verification accuracy and reducing manual review.
- Project Onboarding & Governance — KYC & document upload, geo-tagged project registration, and automated activation after AI + blockchain verification.
- Ongoing Monitoring & Compliance — Monthly image/data uploads, automatic flagging of non-compliance (credit expiry + re-verification workflows) to maintain integrity over time.
- Marketplace & Settlement — A secure marketplace for buy/sell orders, market analytics, and settlement mechanisms that increase liquidity and market access for Indian blue carbon credits.

How this addresses slide challenges

- Transparency & Fraud — Immutable blockchain ledger prevents tampering and provides full provenance.
- Verification Delays — Automated AI validation reduces manual verification times and verification costs.
- Data Quality & Scalability — Standardized ingestion pipelines + Layer-2 blockchain (Polygon) and cloud-native infra to handle high data volumes and 10k+ users.
- Community Adoption & Incentives — Multilingual mobile apps, reward mechanisms, and a ₹2 Cr capacity-building program to onboard coastal communities.

Overview

Goal :

A cloud-native MRV platform that ingests multi-source blue-carbon data, validates it with AI, stores immutable proofs off-chain (IPFS) and on-chain, and tokenizes verified credits for fractional trading via a Layer-2 blockchain.

Key Data Pipeline Sources:

Sentinel-2, GEDI Lidar, SoilGrids, drone photogrammetry, IoT telemetry, field logs.

- Ingestion: Standardized ETL, radiometric & geometric preprocessing, tiling, metadata extraction. Store large assets in S3/GCS + IPFS; keep metadata & time-series in Postgres/Timescale.
- AI/ML: Ensemble models estimate SOC & biomass $\rightarrow$ convert to CO_2e. Anomaly detection flags low-confidence records for human review (target ≈95% accuracy). Confidence score included in attestation.
- Provenance: Every validated report is pinned to IPFS; only CID/hash is written on-chain to preserve auditability and privacy.

Blockchain Architecture:

- Layer choice: Layer-2 (Polygon / Optimism) to reduce gas & allow frequent ops.
- Contracts & Roles:
  - Registry Contract — stores projectID, owner, projectCID (bytes32).
  - Issuance Controller — verifies signed attestations, mints tokens.
  - Credit Token — ERC-20/ERC-1155 for fractional vintages; mint, burn, retire events.
  - Marketplace — escrow/settlement + trade events.
  - Governance/Admin — multisig + timelock for role management and emergency pause.
- Attestation flow: AI/auditor produces report $\rightarrow$ stores on IPFS (reportCID) $\rightarrow$ signs attestation $\rightarrow$ oracle/relayer submits issue tx with signature $\rightarrow$ on-chain controller verifies signature and mints tokens.

Quick Implementation Roadmap (3 phases)

1. MVP (0–3 months): registration, satellite/drone ingestion, AI prototype, testnet tokenization.
2. Scale (3–9 months): add IoT telemetry, marketplace alpha, Layer-2 production deployment.
3. Governance & Integration (9–12 months): NCCR/CCTS integration, audits, community capacity building.

Scalability & Cost Optimizations:

- Batching/Merkle roots: submit batched attestations (Merkle root) instead of many small txs.
- Meta-tx relayer: gas abstraction so non-crypto users can act without holding tokens.
- Use ERC-1155 for vintages/batches if multiple token types are required.

Security, Privacy & Governance:

- No PII on-chain — store only hashes & pointers; encrypted KYC off-chain.
- Multisig & Timelock for admin actions; emergency circuit-breaker (pause).
- Audits & Bounties — formal audits before mainnet; bug bounty program post-launch.

Summary

A first-of-its-kind, blockchain + AI MRV platform that delivers immutable provenance, automated high-accuracy verification, fractionalized credit trading, and community-driven monitoring — built specifically for India's blue-carbon market.

Core Unique Features

1. Blockchain-native Registry & Immutable Provenance

What: All project metadata, issuance events, and audit proofs are anchored to a Layer-2 blockchain (project CIDs / attestations on-chain; large files on IPFS/S3).

How implemented: Registry contract (projectID → CID → owner), issuance controller verifies signed attestations and mints tokens, governance via multisig + timelock.

Why it matters / KPI: Eliminates tampering, shortens dispute resolution time, and provides auditable trails for buyers and regulators. Improves buyer trust metrics (measured as % of buyers requiring on-chain proof).

2. AI-powered Validation & Anomaly Detection

What: Automated preprocessing + ensemble ML models compute SOC/biomass → translate to CO_2e credits; anomaly detectors flag suspicious inputs for human review.

How implemented: Google Earth Engine + model pipeline for indices (NDVI, SOC estimates) → confidence score attached to each attestation → low-confidence cases routed to auditors.

Why it matters / KPI: Reduces manual verification load and aims for ~95% data accuracy in validated reports; measured as reduction in manual verification time and % flagged anomalies.

3. Fractional Tokenization & Marketplace Liquidity

What: Credits tokenized into ERC-style fungible tokens (or ERC-1155 batches) enabling fractional ownership and micro-transactions.

How implemented: Token contract + marketplace contract with escrow/settlement and metadata (vintageCID, confidence score, expiry). Support for fiat settlement rails or stablecoin rails.

Why it matters / KPI: Lowers buyer ticket size, widens buyer base (CSR buyers, small corporates, retail), and increases secondary market activity (trade volume metric).

4. Multi-source, Real-time MRV

What: Continuous monitoring using Sentinel-2, GEDI Lidar, drone surveys, low-cost IoT telemetry and mobile community reports.

How implemented: ETL pipelines ingest satellite/drone/IoT; monthly imagery + on-demand drone flights; IPFS for archiving; metadata & time-series in Timescale/Postgres.

Why it matters / KPI: Higher temporal resolution for detection of degradation or fraud; measured by time-to-detect anomalies and % of projects with continuous telemetry.

5. Community-centric Design & Incentives

What: Multilingual mobile apps for community reporting, incentive / reward mechanisms for verified local monitors, capacity-building initiatives (slide cites a ₹2 Cr program).

How implemented: Mobile client for geo-tagged photos and small surveys; tokenized rewards for validated contributions; training programs for coastal communities.

Why it matters / KPI: Drives ground truth collection, scales monitoring coverage, and improves social buy-in (% projects with local monitors).

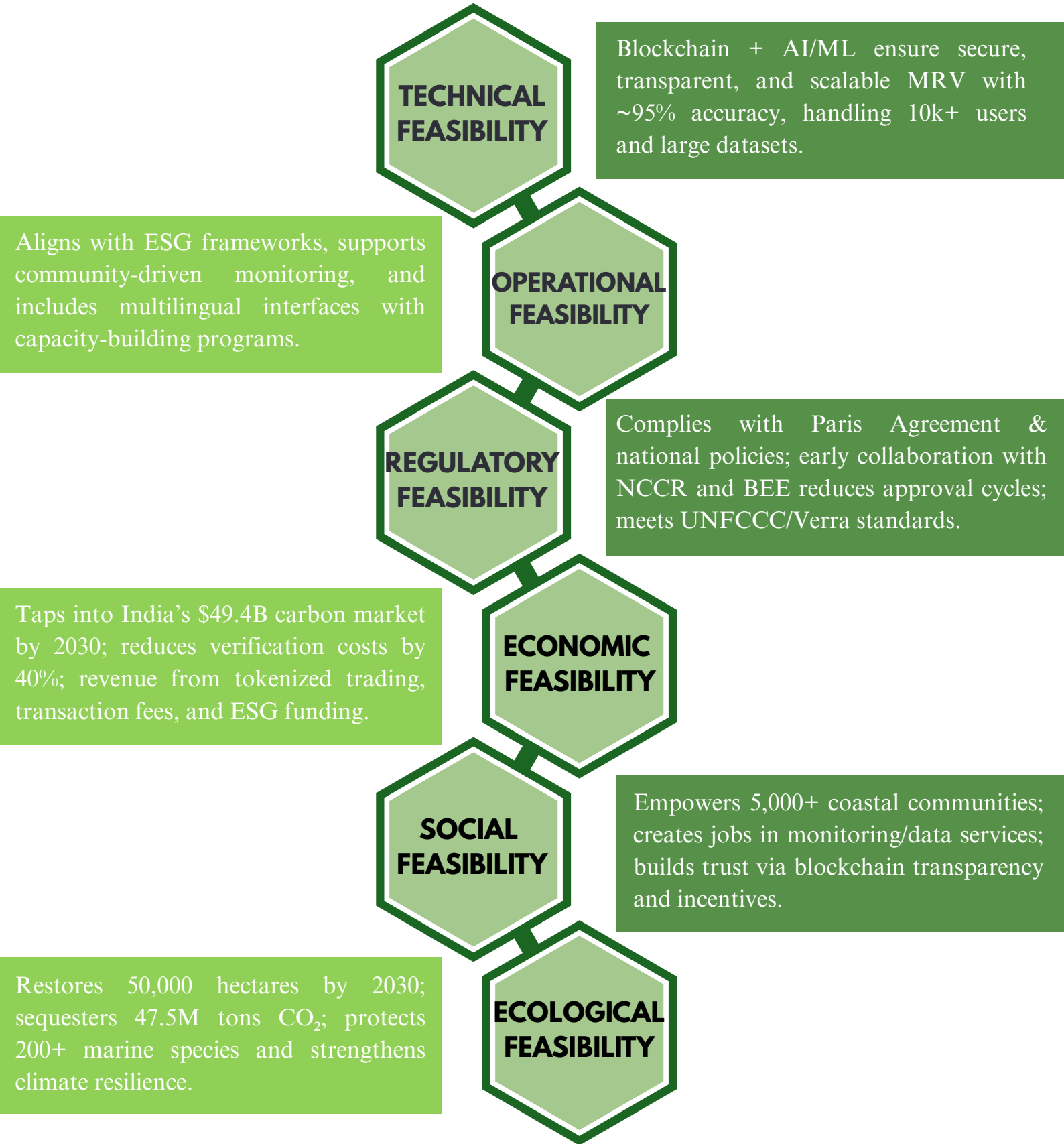## 6. Off-chain Proofs + On-chain Hashing (Privacy by Design)

What: Full datasets and ML artifacts stored off-chain (IPFS/S3/Filecoin); on-chain only stores compact hashes/CIDs and Merkle roots to guarantee integrity without exposing PII.

Why it matters / KPI: Meets privacy/regulatory requirements while maintaining verifiability; measured by audit turnaround time and regulator acceptance rate.

KEY DIMENSIONS

The proposed Blockchain-Based Blue Carbon Registry and MRV system is designed to be technologically robust, socially inclusive, economically viable, and scalable across India's diverse coastal ecosystems. Its feasibility and long-term viability can be assessed across six dimensions:

TECHNICAL FEASIBILITY

Blockchain + AI/ML ensure secure, transparent, and scalable MRV with ~95% accuracy, handling 10k+ users and large datasets.

Aligns with ESG frameworks, supports community-driven monitoring, and includes multilingual interfaces with capacity-building programs.

OPERATIONAL FEASIBILITY

REGULATORY FEASIBILITY

Complies with Paris Agreement & national policies; early collaboration with NCCR and BEE reduces approval cycles; meets UNFCCC/Verra standards.

Taps into India's $49.4B carbon market by 2030; reduces verification costs by 40%; revenue from tokenized trading, transaction fees, and ESG funding.

ECONOMIC FEASIBILITY

SOCIAL FEASIBILITY

Empowers 5,000+ coastal communities; creates jobs in monitoring/data services; builds trust via blockchain transparency and incentives.

Restores 50,000 hectares by 2030; sequesters 47.5M tons CO_2; protects 200+ marine species and strengthens climate resilience.

ECOLOGICAL FEASIBILITY

IMPACT AND BENEFITS

ENVIRONMENTAL IMPACT

- Restore 50,000 ha blue carbon ecosystems by 2030.
- Sequester 47.5M tons CO_2 in 10 years.
- Protect 200+ marine species and habitats.
- Boost coastal resilience against storms/erosion.

ECONOMIC BENEFITS

- Unlock $50B Indian carbon market by 2030.
- Cut MRV costs by ~40% via automation.
- New revenue for communities, NGOs,corporates.

SOCIAL IMPACT

- Involve 5,000+ coastal communities.
- Create jobs in monitoring & restoration.
- Build digital literacy and local capacity.

MARKET POTENTIAL

● MARKET GROWTH

The Indian carbon credit market is projected to grow from $4 billion in 2023 to $49.4 billion (~₹4.1 lakh crore) by 2030, at a CAGR of 43.2%.

● GLOBAL POSITIONING

By leveraging blockchain and MRV transparency, India can position itself as a global leader in verified blue carbon credits, attracting international buyers.
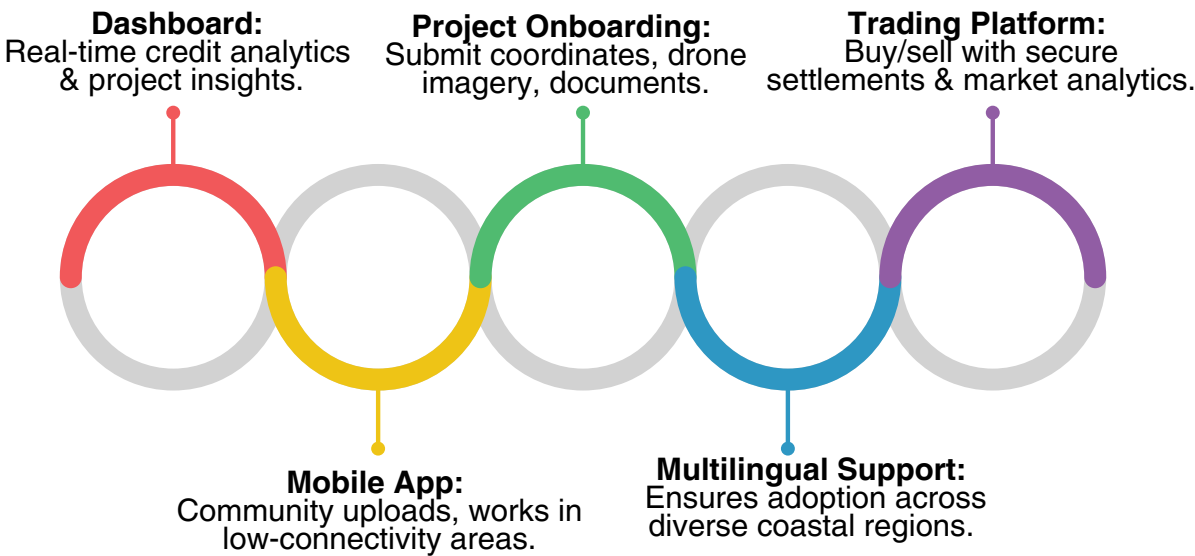
● SEQUESTRATION ADVANTAGE

Blue carbon ecosystems (mangroves, seagrasses, salt marshes) offer superior sequestration efficiency — up to 10x greater than forests.
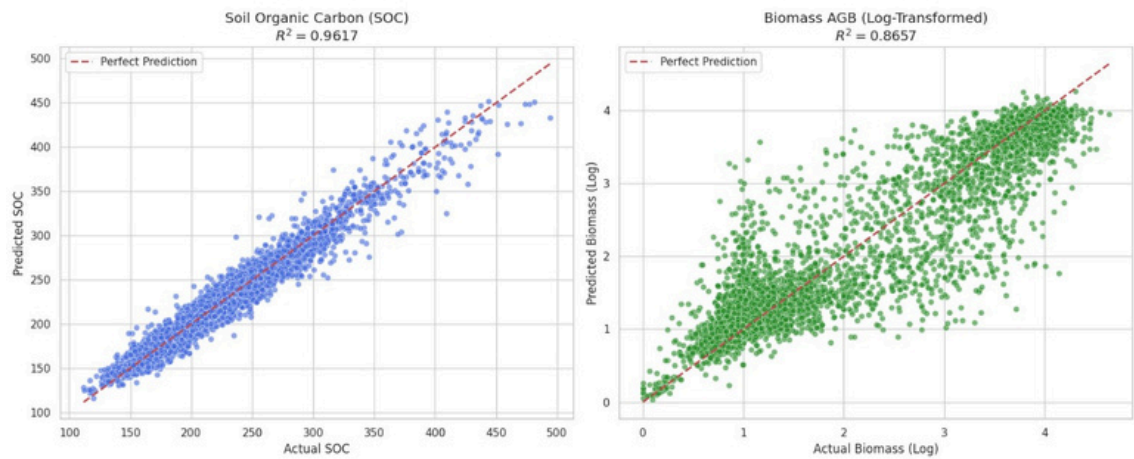
● UNIQUE DIFFERENTIATORS

Differentiators like fractional credit trading and AI-driven validation increase inclusivity and market credibility.

USER INTERFACE

Dashboard:
Real-time credit analytics & project insights.

Project Onboarding:
Submit coordinates, drone imagery, documents.

Trading Platform:
Buy/sell with secure settlements & market analytics.

Mobile App:
Community uploads, works in low-connectivity areas.

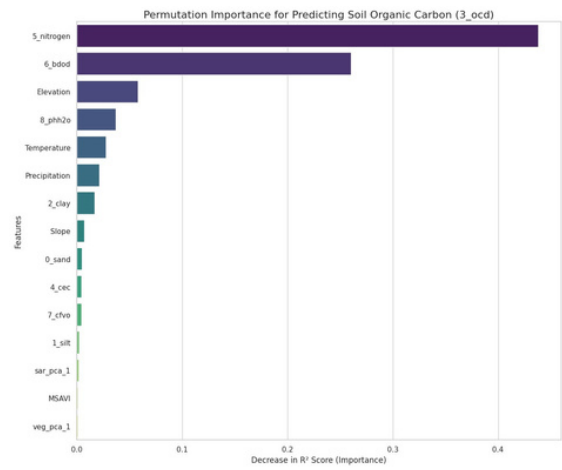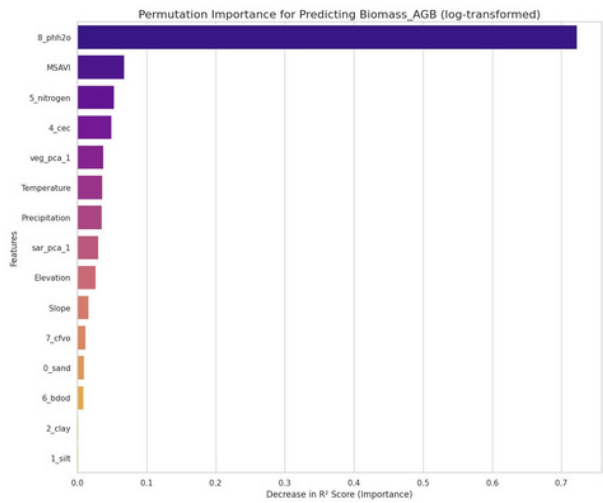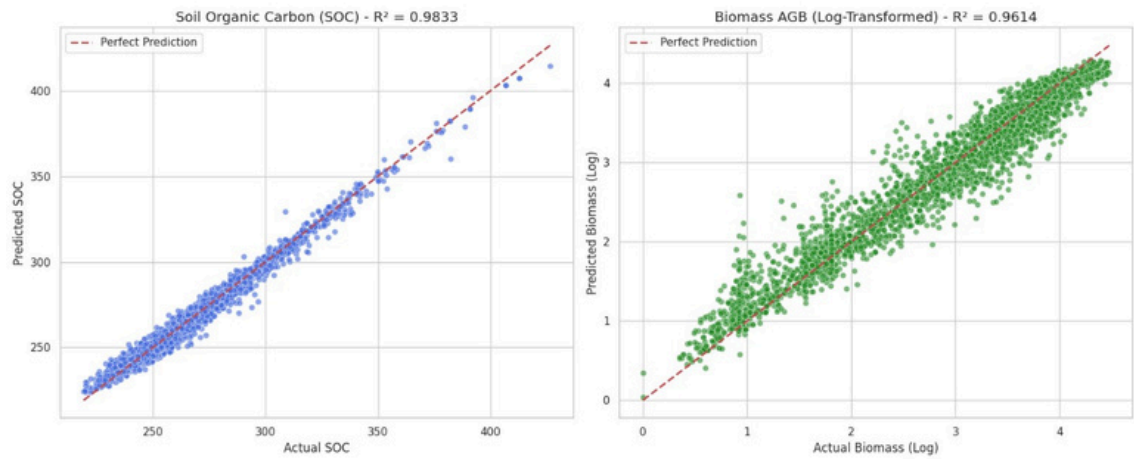**Multilingual Support:**
Ensures adoption across diverse coastal regions.

Model Prediction vs. Actual Values on Test Data

Model Prediction vs. Actual Values (Trained on Full Data)

- **Blue Carbon Science**: NOAA, Blue Carbon Initiative.
- **Market Studies**: Fitsol (Future of Carbon Credits), Grand View Research.
- **Datasets**:

  ESA Sentinel-2, SoilGrids, Google Earth Engine, Harmonized Landsat, GEDI Lidar.
- **Registries**: UNDP National Carbon Registry.
- **Acknowledgements**:

  Ms. Soniya Gupta (CJBS), Prof. Somsubhra Chakraborty (IITKgp).

ANNEXURE

The annexure contains supporting technical details and extended resources:

System Architecture Diagrams – Detailed workflow of blockchain, AI validation, and MRV integration.

AI Model Performance – SOC accuracy of 96.17% and Biomass prediction accuracy of 86.57%.

Datasets Used – Sentinel-2, Harmonized Landsat, GEDI Lidar, and global tidal wetland change data.

Pilot Region Case Studies – Example restoration sites with baseline carbon measurements.

Training & Capacity Building Plan – Curriculum for NGOs and communities to ensure digital literacy and monitoring skills.

Policy Alignment Notes – Mapping of the solution with India's climate policies, Paris Agreement targets, and ESG frameworks.