

From Soil to Satellite

Unlocking Soil Organic Carbon in Precision Farming

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Introduction

- Soil Organic Carbon (SOC) is the backbone of soil health & crop productivity.
- Precision farming offers tools to monitor and enhance SOC.

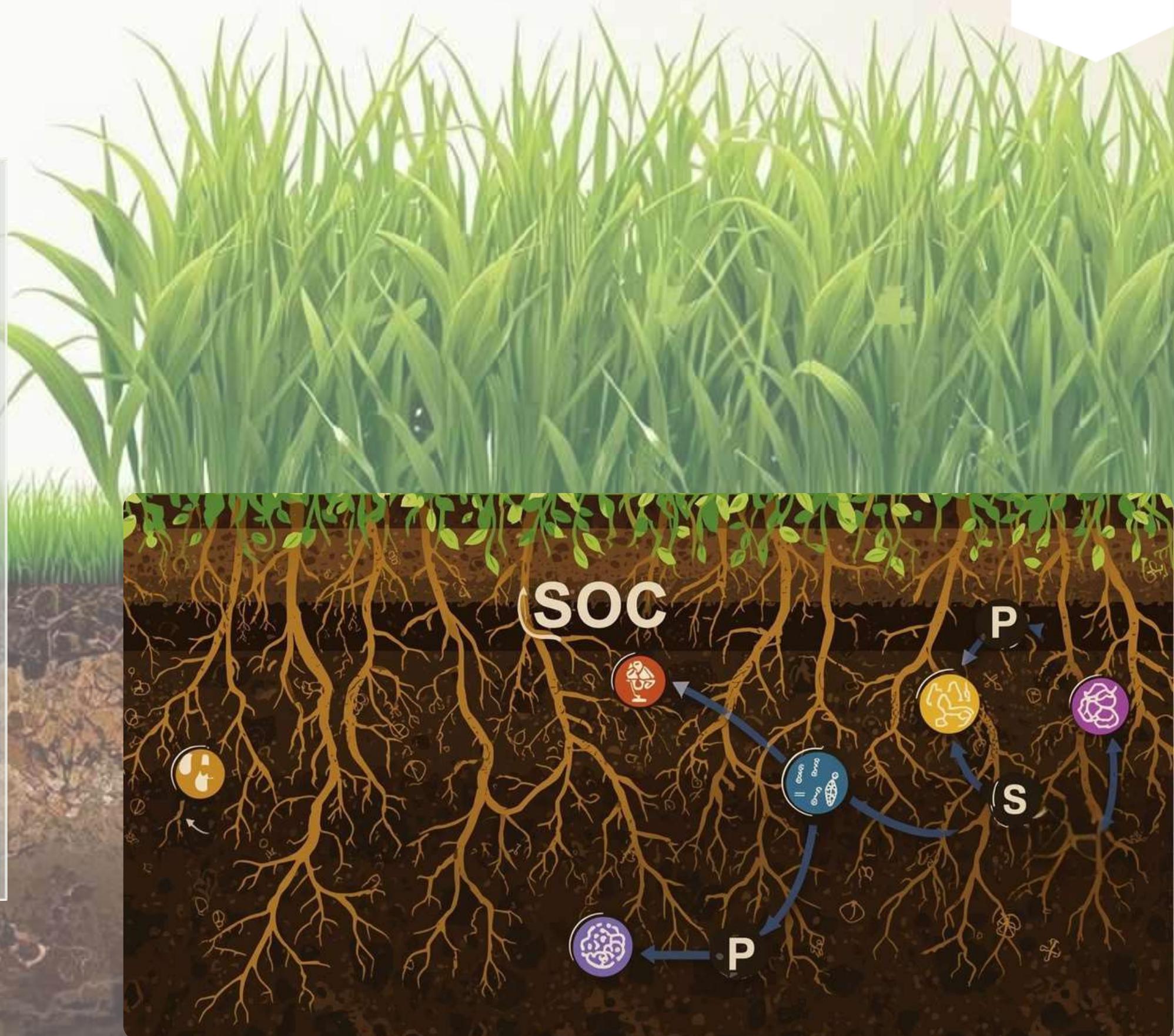


Soil Organic Carbon: Foundation of Soil Quality

- SOC = fraction of organic matter that drives **soil productivity**.
- Functions:
 - Enhances **nutrient cycling (N, P, S)**
 - Regulates soil pH and cation exchange capacity (CEC)
 - Acts as a reservoir for **microbial energy**.
- Strong correlation between SOC and **crop yield sustainability**.

Structural Role of SOC

- SOC improves **soil aggregation** → better porosity & aeration.
- Increases **water-holding capacity**, especially in sandy soils.
- Enhances **bulk density reduction**, making soils less compact.
- Protects soil from **erosion** and improves resilience under stress.



Driver of Microbial Diversity

- Provides **energy source** for bacteria, fungi, and soil fauna.
- Enhances **enzyme activity** (decomposition, mineralization).
- Promotes beneficial organisms → suppresses soil-borne diseases.
- Higher SOC = increased **biological nitrogen fixation** in legumes.



SOC: Dual Role in Fertility & Climate Action

- **Fertility Benefits:**

- Increased availability of macronutrients & micronutrients.

- Improved **nutrient-use efficiency** in crops.

- **Climate Benefits:**

- Acts as a **carbon sink**, reducing atmospheric CO₂.

- SOC stability enhances long-term **sustainability** of agriculture.

- SOC is a **critical indicator** for soil health monitoring frameworks (FAO, IPCC).



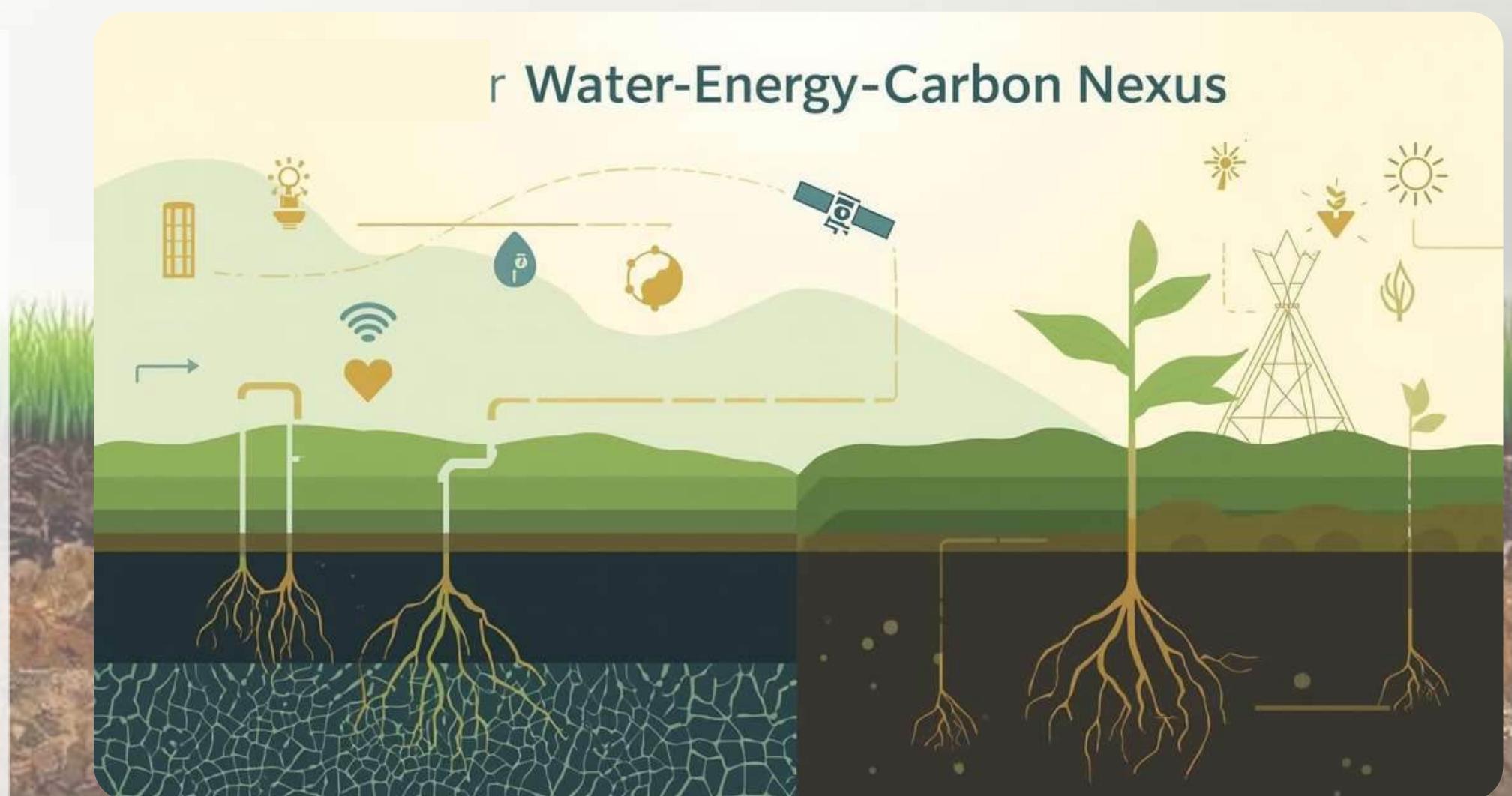


• Targeted Input Management to Build SOC

- **Geospatial soil sampling + GIS mapping** → identifies SOC variability.
- **Variable Rate Technology (VRT)** applies compost, manure, or biochar precisely.
- **Integration with AI/ML nutrient models** ensures balanced C:N ratio.
- Reduces nutrient losses, increases carbon stabilization in soil aggregates.

Water-Energy-Carbon Nexus

- **Soil moisture sensors & IoT probes** optimize irrigation scheduling.
- **Remote sensing indices (NDWI, SMAP data)** track soil water dynamics.
- Maintaining optimal soil moisture → improves microbial carbon turnover & root biomass.
- Avoids carbon loss from waterlogging and erosion.



Technology-Enabled Soil Conservation Practices

- **No-till, cover crops, crop residue retention** → reduce SOC loss.
- **Drones & satellites** monitor crop residue cover, biomass incorporation.
- Machine-learning algorithms classify **cover crop impact on SOC stocks**.
 - Enhances soil aggregation, reduces disturbance-induced SOC oxidation.

Decision Support for SOC Enhancement

- **Satellite-derived SOC maps (Sentinel-2, Landsat, Hyperspectral)** integrated into models.
- **AI/ML predictive analytics** forecast SOC changes under different management.
- Decision Support Systems (DSS) recommend **carbon-positive practices**.
- Enables **carbon credit monitoring & reporting** for farmers.



Remote Sensing for Soil Organic Carbon Mapping

- Soil Organic Carbon (SOC) is a key indicator of soil health and carbon sequestration potential.
- Traditional SOC mapping: Labor-intensive soil sampling and lab analysis.
- Satellite-based approaches: Enable large-scale, high-resolution, temporal monitoring of SOC.
- Key satellite data sources:
 - Optical sensors:** Landsat, Sentinel-2, MODIS
 - Radar sensors:** Sentinel-1, RADARSAT
 - Hyperspectral sensors:** PRISMA, EnMAP

SOC Mapping Workflow: Data Fusion & Modeling

- Data Fusion

Combine optical, radar, and hyperspectral data for robust SOC estimation.

- Machine Learning & AI:

Algorithms: Random Forest, XGBoost, CNNs

Predict SOC at high spatial resolution using multisource satellite data.

- Advantages:

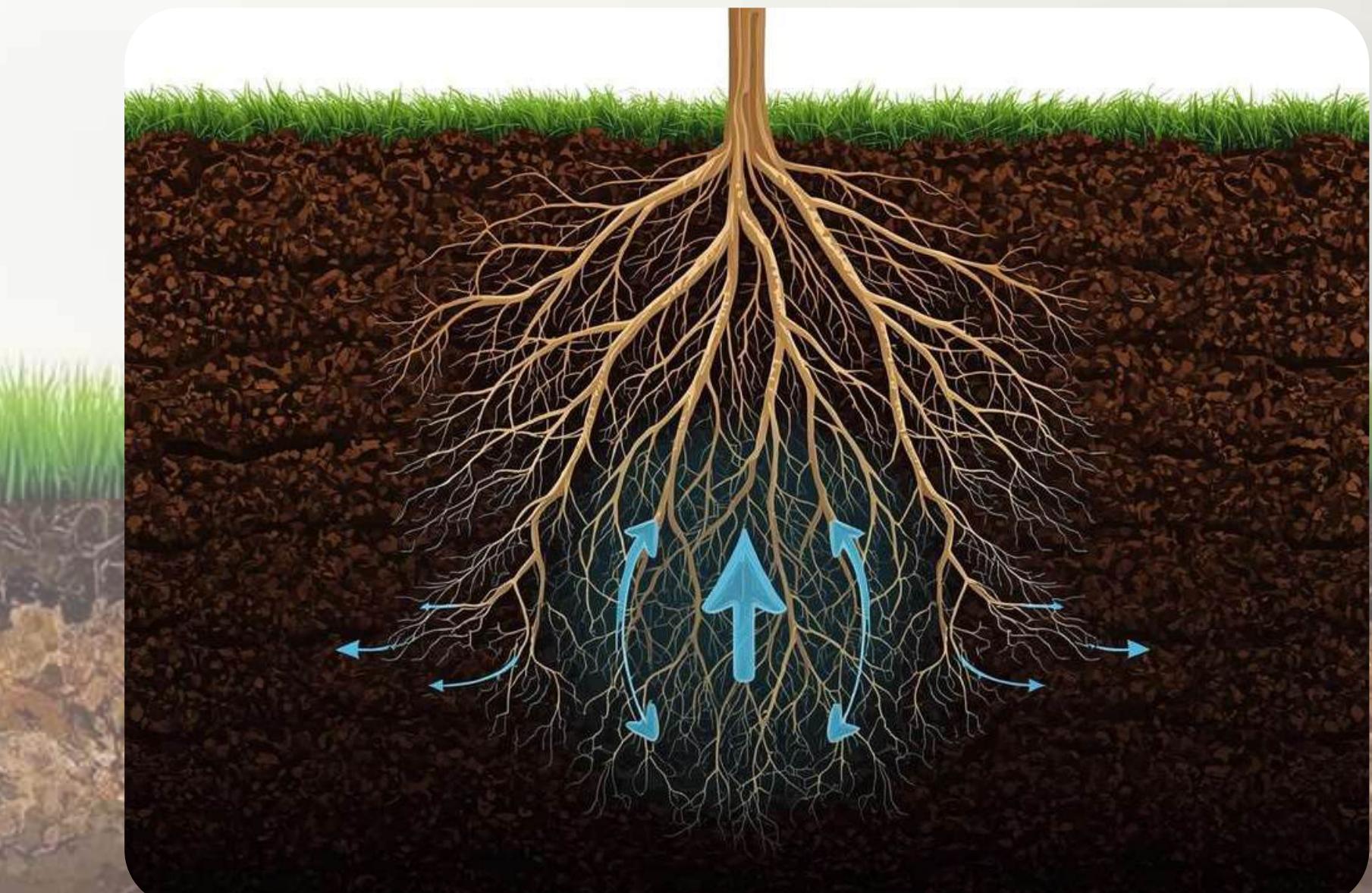
Large-area coverage, temporal monitoring, cost-effective vs field surveys.

SOC Influence on Nutrient Availability and Growth

- SOC is a primary reservoir of N, P, and S: gradual mineralization supports sustained nutrient supply.
- Improves cation exchange capacity (CEC), enhancing nutrient retention.
- Promotes microbial activity and beneficial symbionts (e.g., mycorrhizae), boosting root growth.
- Higher SOC → better soil aggregation → improved root penetration and aeration.

Role of SOC in Soil Moisture Dynamics

- SOC increases soil porosity and aggregate stability → improves water infiltration and storage.
- Soils rich in SOC retain 20–30% more plant-available water than low-SOC soils.
- Reduces surface runoff, mitigates drought stress, and improves irrigation efficiency.
- Enhances resilience of crops to erratic rainfall and climate extremes.



SOC for Soil and Crop Resilience

- High SOC buffers soils against erosion, compaction, and salinization.
- Supports recovery after stress events (floods, drought, heat).
- Contributes to climate mitigation via carbon sequestration.
- Integrated management (cover crops, residue retention, compost) increases SOC → sustained productivity under variable conditions.



Carbon Sequestration: Concept and Importance



- **Carbon Sequestration (CS):** Process of capturing atmospheric CO₂ and storing it in soil, biomass, or oceans.
- **Soil Organic Carbon (SOC) as a Key Sink:**
SOC storage = largest terrestrial carbon reservoir (1500–2000 Pg globally).
- **Relevance to Climate Action:**
Reduces greenhouse gas (GHG) concentrations.
Supports national and global carbon accounting (IPCC guidelines).
- **Monitoring is critical for validating mitigation strategies.**





SOC Monitoring in Climate Mitigation Strategies

- Supports **Nationally Determined Contributions (NDCs)** and carbon credit schemes.
- Identifies high sequestration potential areas for **reforestation, agroforestry, and conservation agriculture**.
- Enables **decision support** for sustainable land management and carbon trading.
- Continuous monitoring ensures verification of climate action targets.

Carbon Credits: Linking Agriculture and Climate Finance

- **Carbon Credits:** Tradable certificates representing 1 ton of CO₂-equivalent (CO₂e) reduction or sequestration.
- Agriculture's role: SOC accumulation, agroforestry, conservation tillage, and cover cropping contribute to carbon sequestration.
- Global market potential: Estimated \$200B+ by 2030 in agriculture-based carbon credits.
- Benefits: Financial incentives for farmers, promotes adoption of sustainable practices.

High-Impact Practices for SOC Enhancement

- **Conservation Agriculture:** Minimal tillage, residue retention → reduces SOC loss.
- **Agroforestry & Silvopasture:** Tree integration → increased biomass and SOC storage.
- **Cover Crops & Crop Rotation:** Enhance soil structure, microbial activity, and SOC accumulation.
- **Biochar Application:** Stabilizes carbon in soil for decades, improves fertility and water retention.
- **Quantitative impact:** Practices can increase SOC by 0.2–0.5% per year.

Carbon Credit Market & Sustainable Agriculture Potential

- **Economic Incentives:** Farmers gain revenue streams through verified SOC sequestration.
- **Policy Alignment:** Supports NDCs, climate-smart agriculture targets, and ESG commitments.
- **Investment & Innovation:** Precision agriculture, AI/ML, and remote sensing technologies enhance carbon credit verification.
- **Scalable Impact:** Regional and global mapping of SOC allows prioritization of high sequestration zones.

Key Takeaways

- SOC is vital for soil, crops & climate
- Precision farming is the game-changer in monitoring SOC
- Opportunities exist for both **sustainability & profitability**
- Collaboration is essential for scaling solutions
- **PlanetEye FarmAI** is committed to enabling this future



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