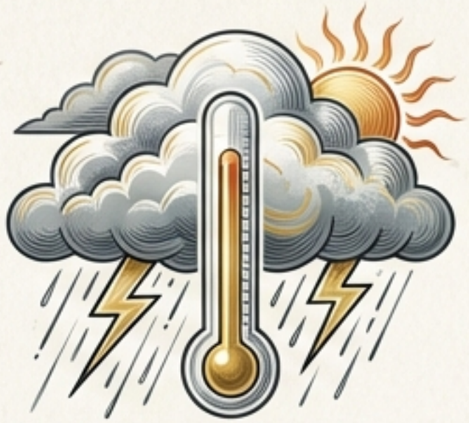
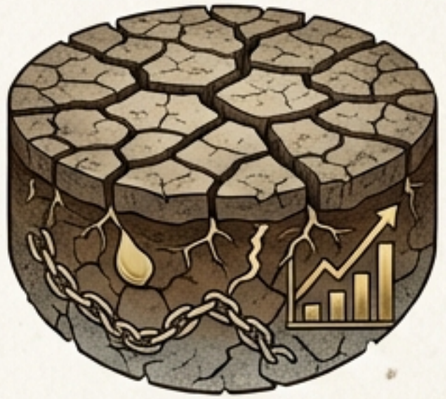
Roots of Resilience: Agroecology as India's Climate Strategy

A comprehensive framework for Mitigation, Adaptation, and Climate Finance in Indian Agriculture

Context: This document outlines a roadmap to transition India's 140 million hectares of cropland from a carbon source to a carbon sink, securing livelihoods for millions of farmers

Ramanjaneyulu GV

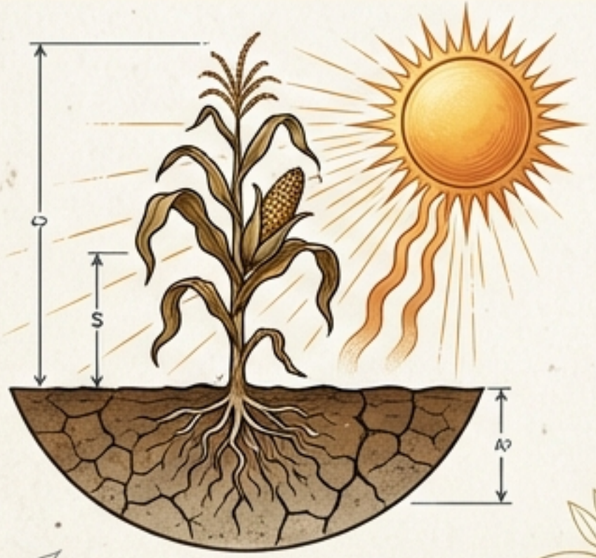
Agriculture at the Intersection of Hazard, Exposure, and Vulnerability

Climate Risk =  ×  × 

Hazards
(Extreme weather, Temp variability)

Exposure
(Physical location, Crop limits)

Vulnerability
(Socio-economic fragility, Soil degradation)



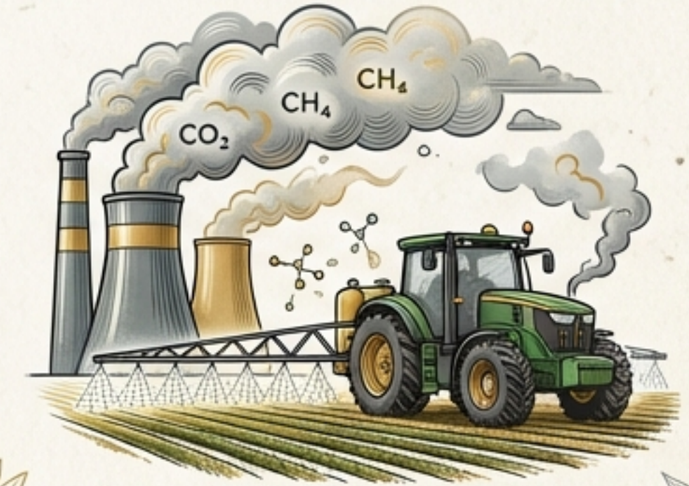
The Double Agent Problem

The Victim

Sensitive to physical impacts (drought, heat stress).

The Perpetrator

Drives emissions via synthetic inputs & land-use change.

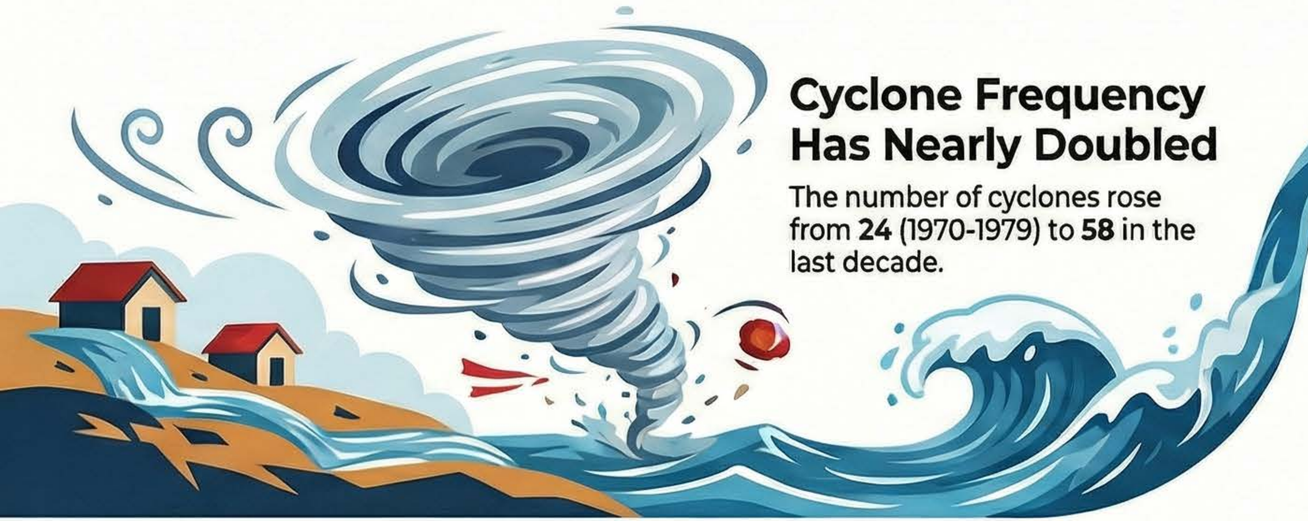


Key Takeaway

Solution: Must simultaneously reduce Hazard contribution (Mitigation) and decrease Vulnerability (Adaptation).

India's Escalating Climate Crisis: A Surge in Extreme Events

India is witnessing a significant rise in extreme climate events. Data reveals a sharp upward trajectory in the frequency of cyclones and floods since the 1970s, alongside expanding drought-prone regions that now effect millions of citizens and the majority of the nation's agricultural land.



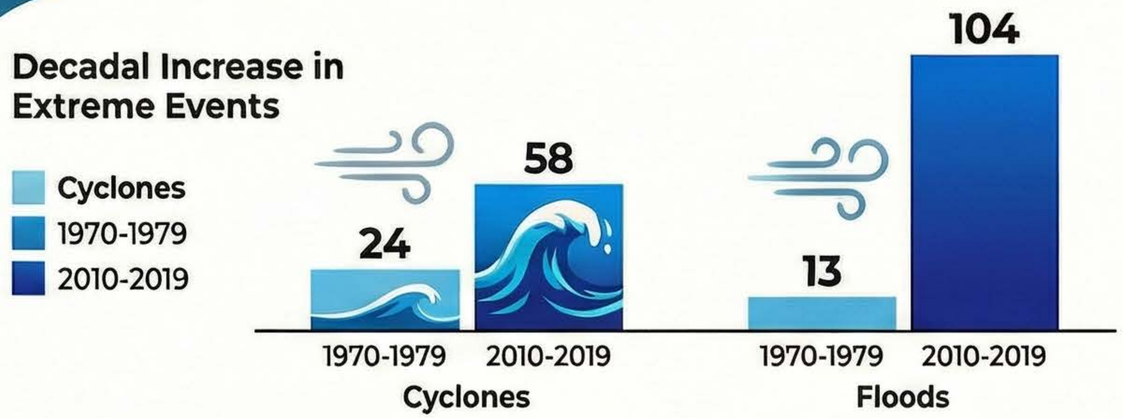
Cyclone Frequency Has Nearly Doubled

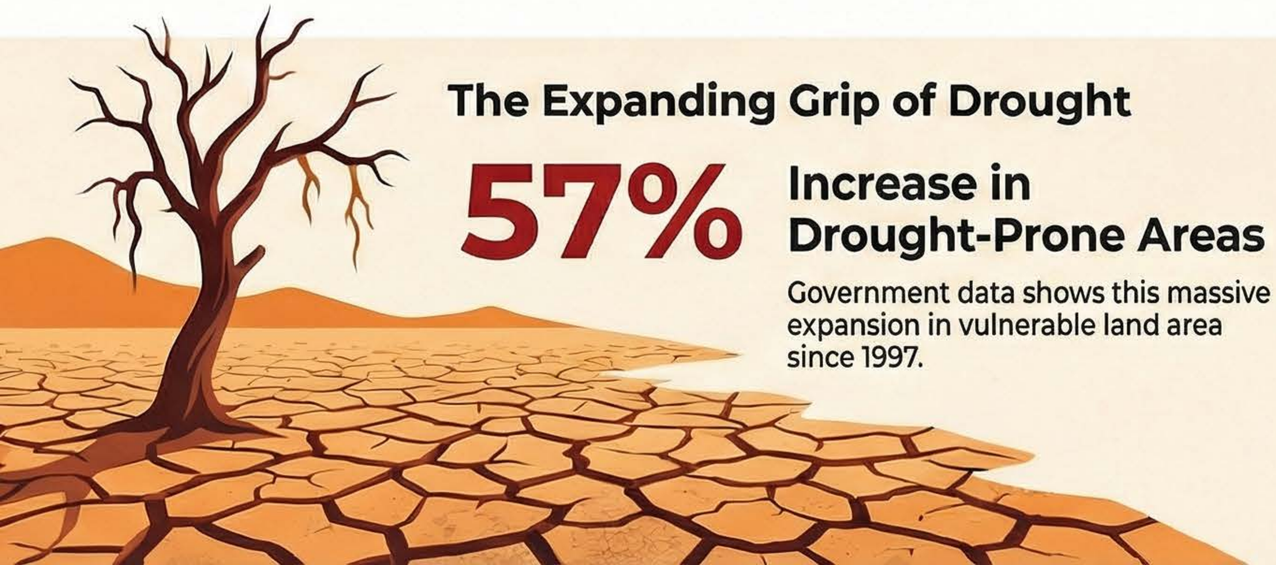
The number of cyclones rose from **24** (1970-1979) to **58** in the last decade.

Extreme Floods Surge Since the Late 1990s

Flood events spiked from 13 in the 1970s to **104** between 2010 and 2019.

Decadal Increase in Extreme Events





The Expanding Grip of Drought

57% Increase in Drought-Prone Areas

Government data shows this massive expansion in vulnerable land area since 1997.

50 Million People Affected Annually

This staggering population is impacted by drought every single year.

68% of Sown Area At Risk

Over two-thirds of India's cultivated land faces varying degrees of drought annually.

Agriculture Under Siege: The Direct Impact on Food Security

Farming is the sector most exposed to climate risks, threatening the livelihood of millions.

Yield Decline

Crop yields for staples like rice, wheat, and pulses are declining due to extreme heat and erratic monsoons.

Disrupted Seasons

Shifting growing seasons disrupt traditional planting/harvesting cycles.

Soil Degradation

Accelerated by high temperatures and unseasonal rains, leading to erosion.

Biotic Stress

Warmer climates increase pest and disease proliferation.

Agriculture: Both Victim and Contributor

The Impact on the Farm

Heat Stress: Rising temps affecting wheat phenology in Indo-Gangetic Plains.

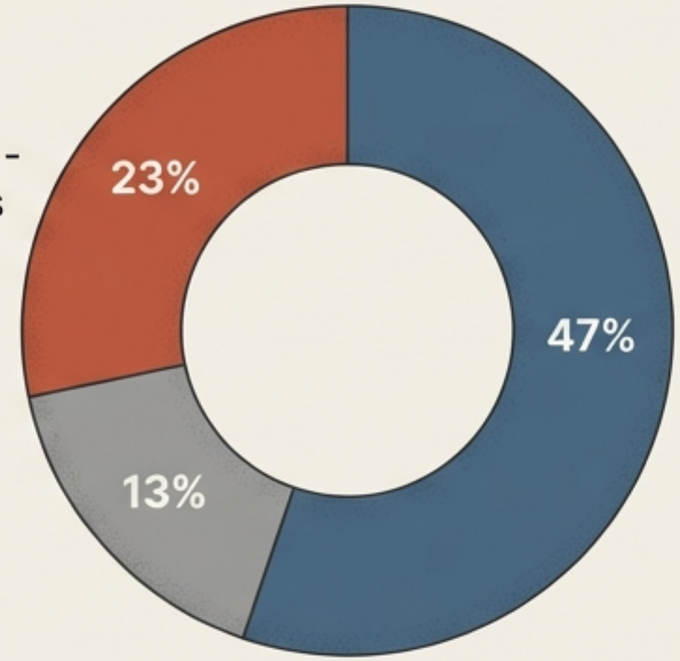
Water Security: Glacial melt threatening river basins.

Biotic Stress: Pest pressures shifting spatially.

Sources of Agricultural GHG Emissions (14-18% of India's Total)

Nitrous Oxide (N_2O) - Synthetic Fertilizers (18M+ tonnes/yr)

CO_2 - Energy & Machinery



Methane (CH_4) - Rice Cultivation (17.5M ha flooded)

Key Takeaway: The dual role creates a responsibility and a massive opportunity: agriculture must be central to India's climate strategy.

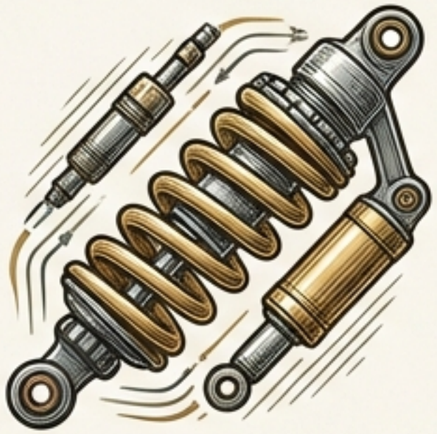
Defining the Scope: Mitigation, Adaptation, and Resilience

Mitigation
(The Stop)

Reducing sources or enhancing sinks of GHGs.

Agroecology: Carbon sequestration, N_2O reduction.

Adaptation
(The Cope)



Adjustments in systems in response to climatic stimuli.

Agroecology: Crop diversification, drought-tolerant varieties.

Resilience
(The Strengthen)

Capacity to **absorb** disturbance and reorganize while retaining function.

Agroecology: Self-regenerating systems, input autonomy.

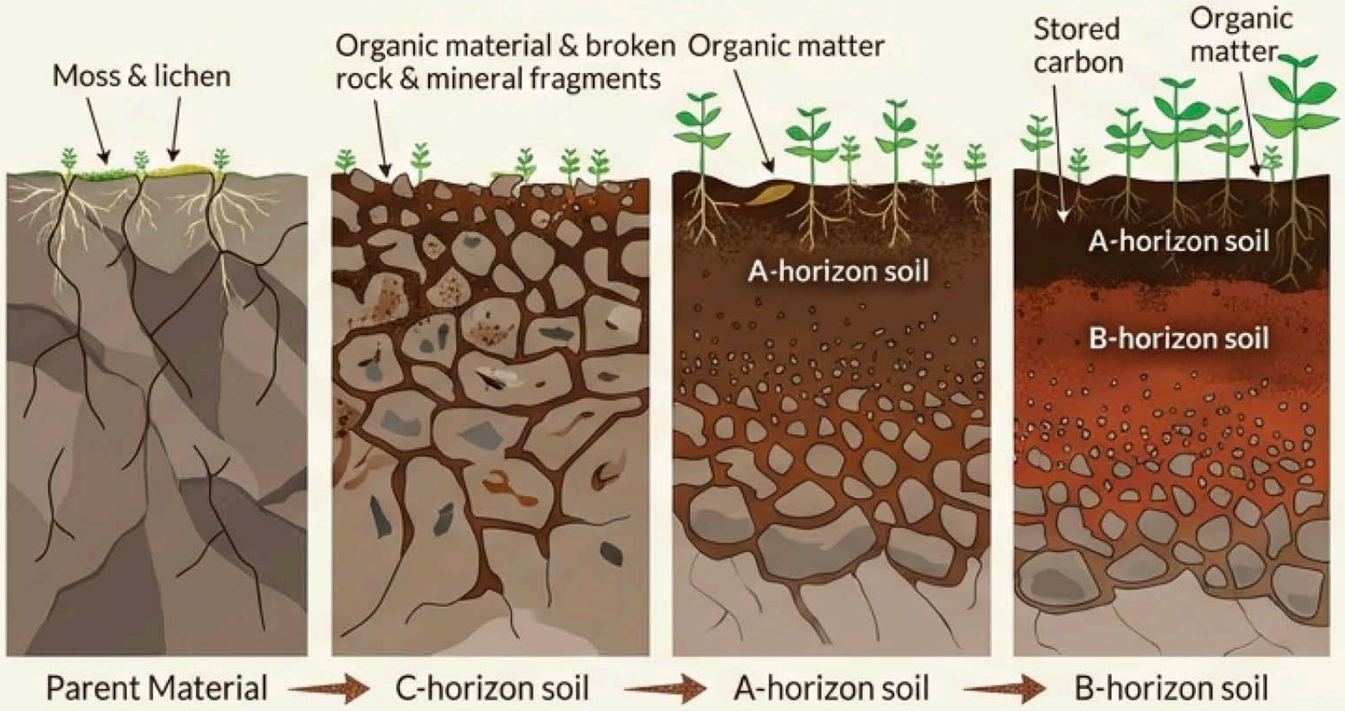
Insight: Resilience goes beyond 'bouncing back"—it is the capacity to **transform**.

The Living Skin of the Earth

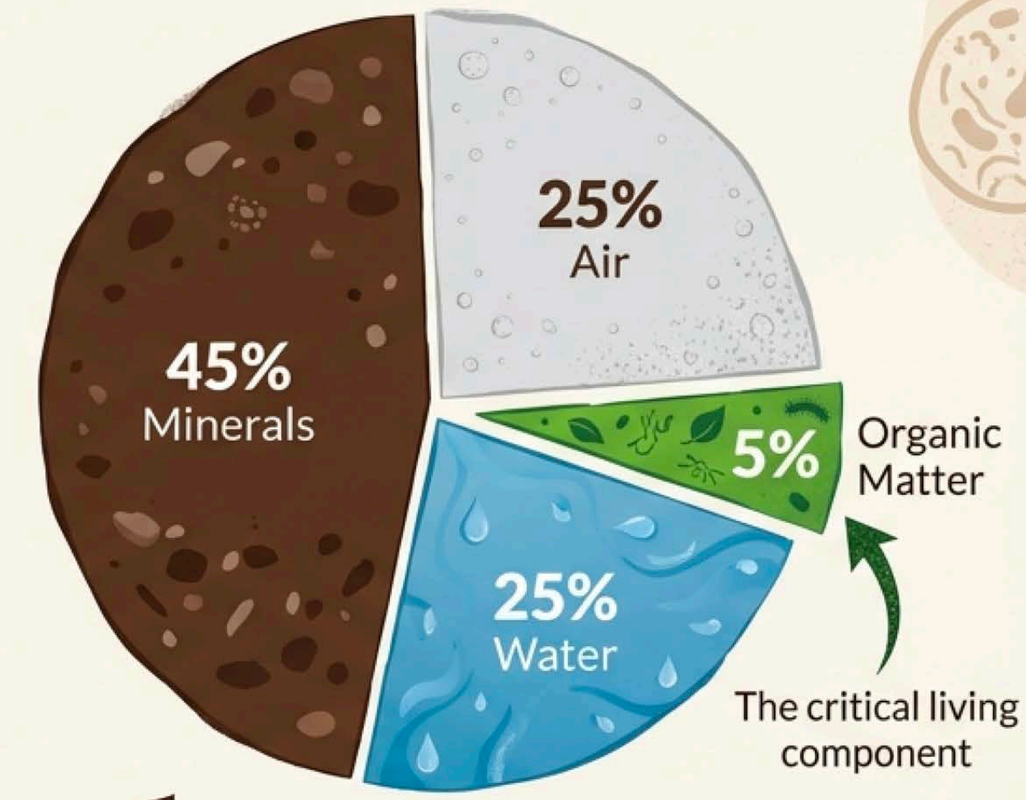
The Cost of Time

200 Years

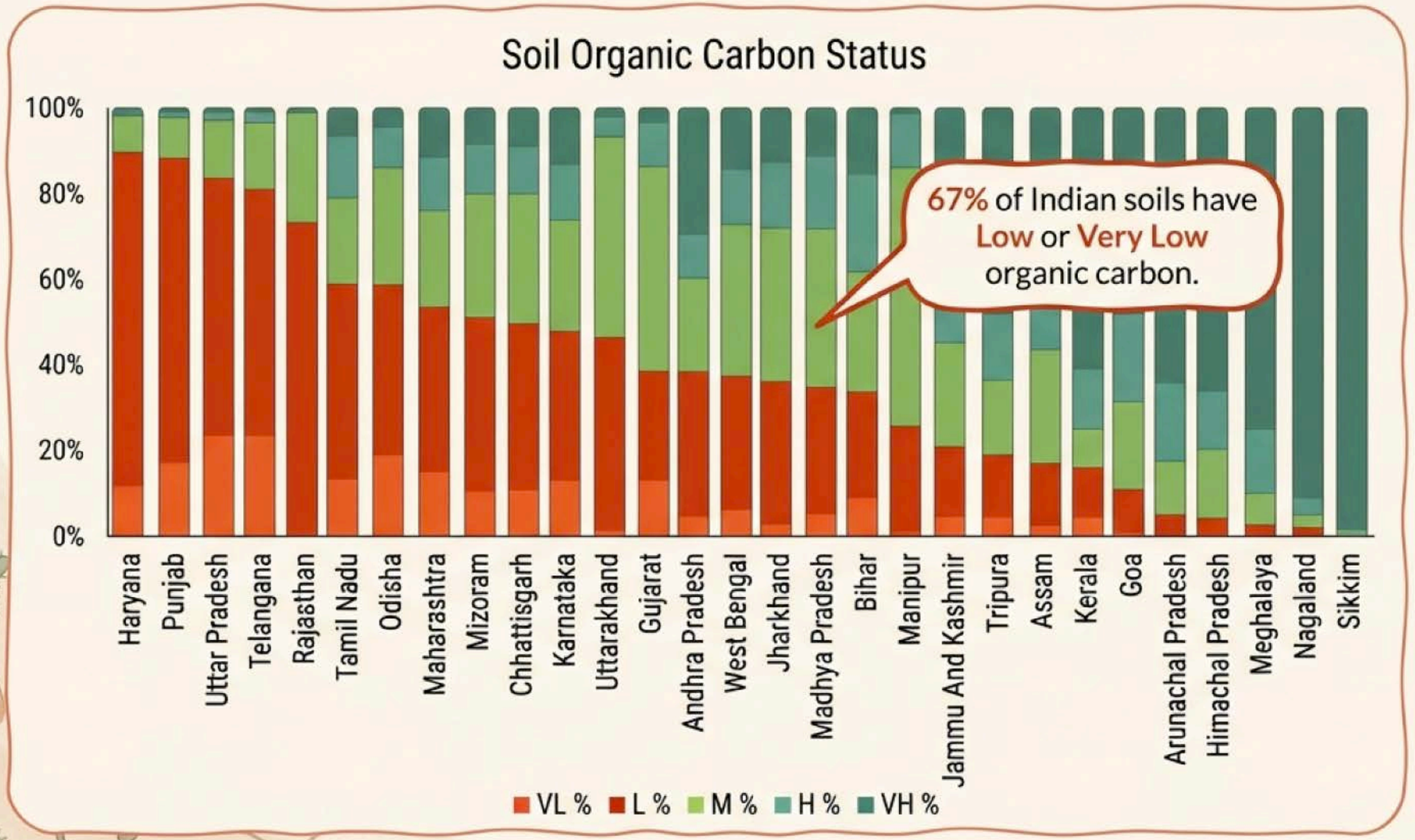
Time required to form just 1 cm of topsoil.



Composition of Healthy Soil



The Carbon Crisis in Indian Soils



Key Insight:

The Sponge Effect

A 1% increase in Soil Organic Matter (SOM) holds ~60,000 liters more water per acre.

Current Status: Dropped from 1.3% (1950s) to < 0.3% (Today)

From Reservoirs to Extraction: The Shifting Hydrology of Rice

Traditional Water-Harvesting Cycle

Rice as a Natural Reservoir

Low-lying fields captured monsoon rain, slowing water down to allow for deep soil infiltration.

Aquifer Recharge

Rainwater infiltrated the soil profile to recharge recharge shallow aquifers and open weils for later use.

Supporting Seasonal Diversity

Stored groundwater allowed for "Rabi" crops like pulses and oilseeds, diversifying farm income.

Ecological Logic Comparison

	Traditional Hydrology		Modern Hydrology
Primary Function	Water Harvesting	VS	Water Consuming
Soil Structure	Porous/ Infiltrative	VS	Compacted "Hard Pan"
Water Source	Natural Monsoon Rain	VS	Pumped Groundwater

Modern Extractive Vicious Cycle

Soil Puddling & the "Hard Pan"

Intensive tilling creates a compacted layer below the soil, severely limiting natural groundwater recharge.

Increased Rainwater Runoff

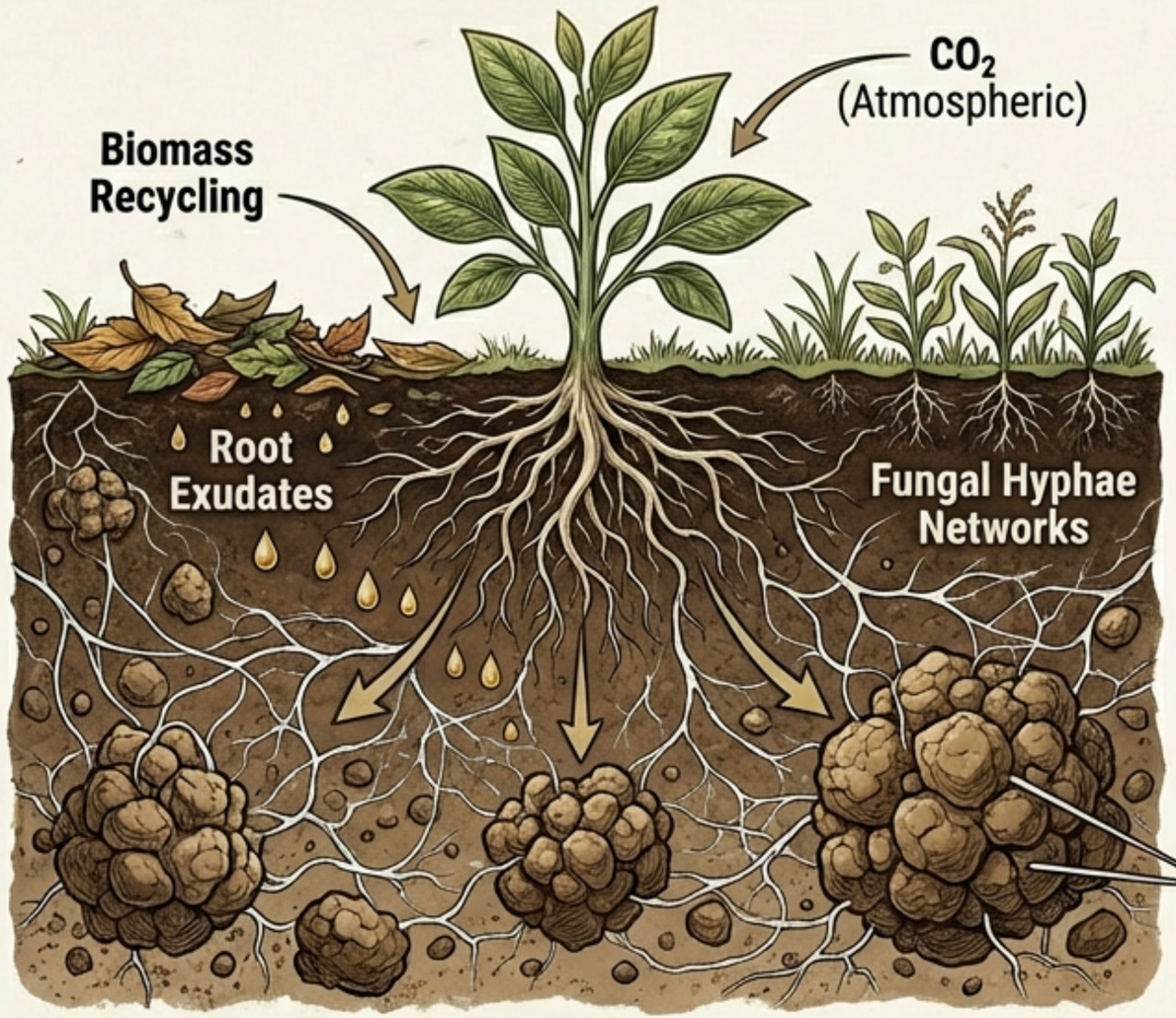
Compacted fields cannot absorb excess rain, causing valuable water to be lost as runoff.

The Vicious Cycle of Extraction

Reduced infiltration forces a reliance on pumping groundwater to maintain flooded conditions.

The Carbon Lever: Turning Soil into a Sink

The Input:
Biomass recycling & cover crops capture atmospheric CO_2.



The Stabilization:
Reduced tillage preserves fungal hyphae, protecting SOC from oxidation.

Result: Improved SOC = **Mitigation** (Sequestration) + **Resilience** (Water Retention).

Mitigation Engine I: The Soil Carbon Opportunity

1% increase in Soil Organic Carbon = ~15 ·30 tonnes CO_2 sequestered per hectare.

National Potential: **0.4%** increase across 140M ha = **840 Million Tonnes CO_2.**

Organic Matter Addition

FYM, Green Manures (Dhaincha)

Soil Protection

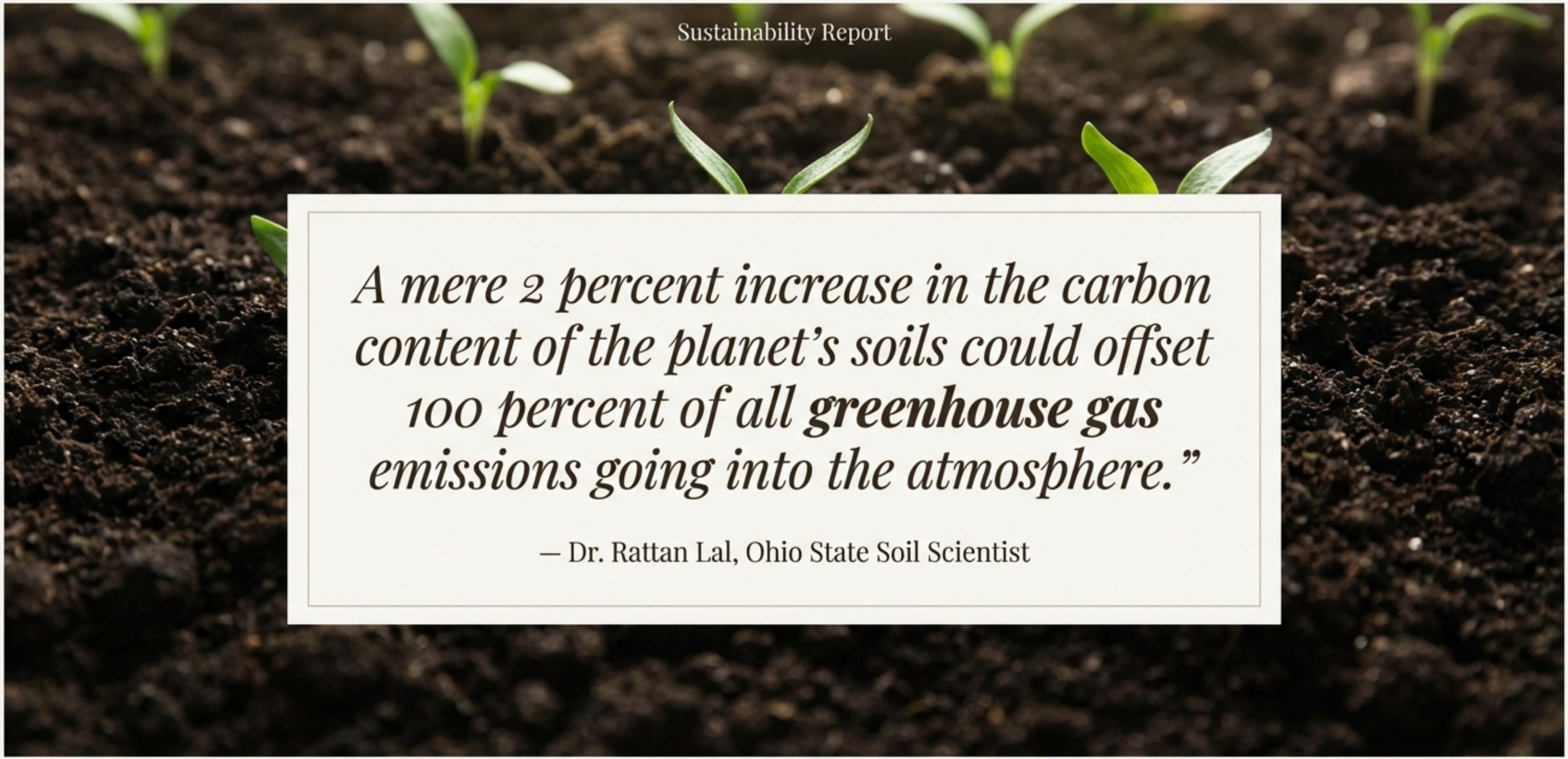
Reduced Tillage (prevents oxidation) + Biomass Recycling

Sequestration

Stable Humus Formation

Evidence:

Andhra Pradesh Natural Farming showed SOC increase from 0.42% to 0.64% in four years.



A mere 2 percent increase in the carbon content of the planet's soils could offset 100 percent of all ***greenhouse gas*** *emissions going into the atmosphere."*

— Dr. Rattan Lal, Ohio State Soil Scientist

0.1% increase in Soil Organic Carbon = Sequestration of **2.9 tons** of CO_2

Mitigation Engine II: Fixing Nitrogen and Methane

The Nitrogen Nexus (N_2O)

Problem: 18M+ tonnes synthetic N used. 298x warming potential.

Solution: Biological Nitrogen Fixation (Pulses) + Precision Timing.

30% reduction in Synthetic N = Taking 1.2 Million cars off the road.

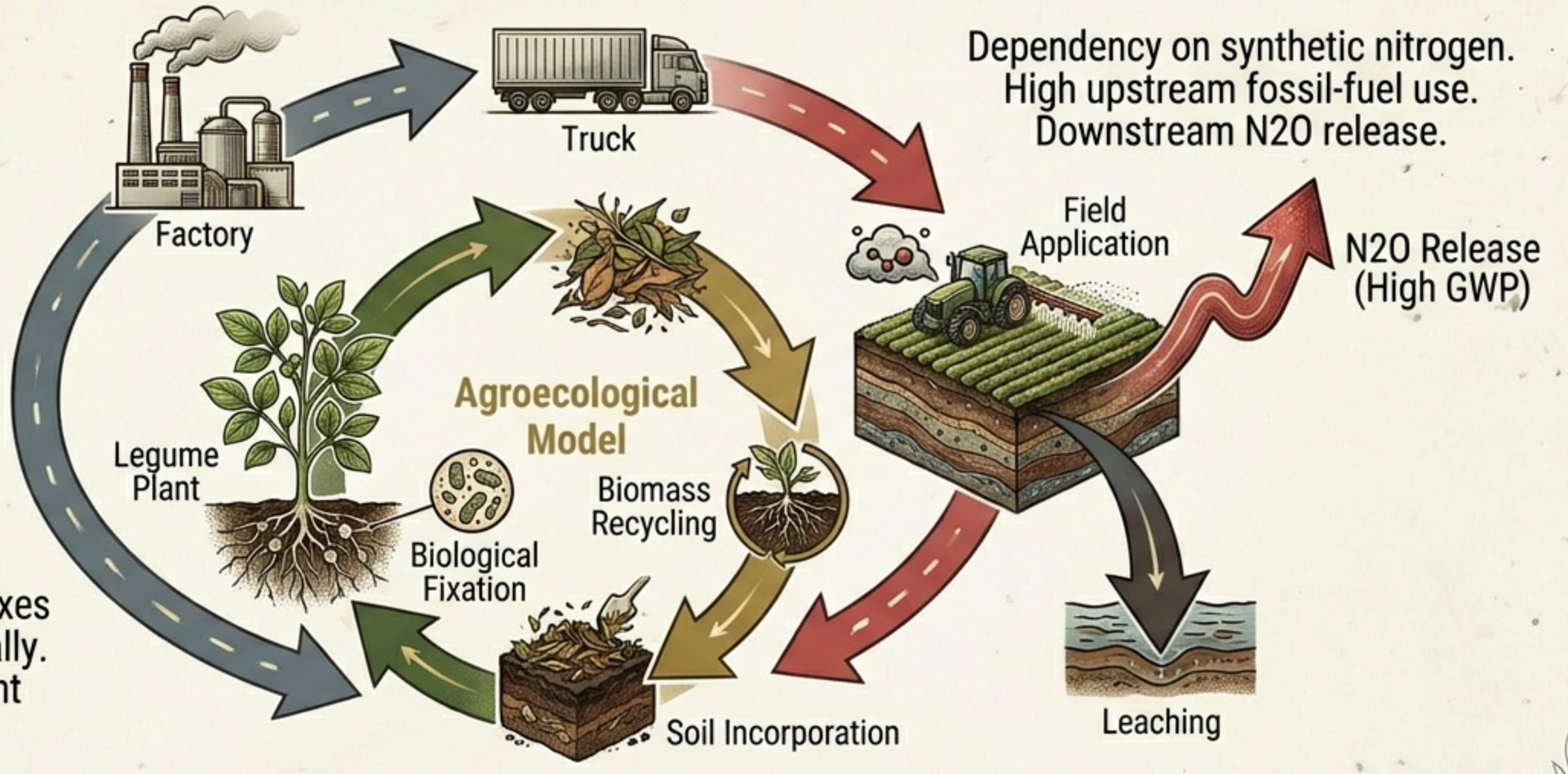
The Rice Methane Problem (CH_4)

Problem: Anaerobic conditions in 17.5M ha of flooded rice.

Solution: AWD, SRI, and Aerobic varieties.

Improved management on 25% of rice area = Emissions of India's entire domestic aviation sector (42-70M tonnes CO_2-eq).

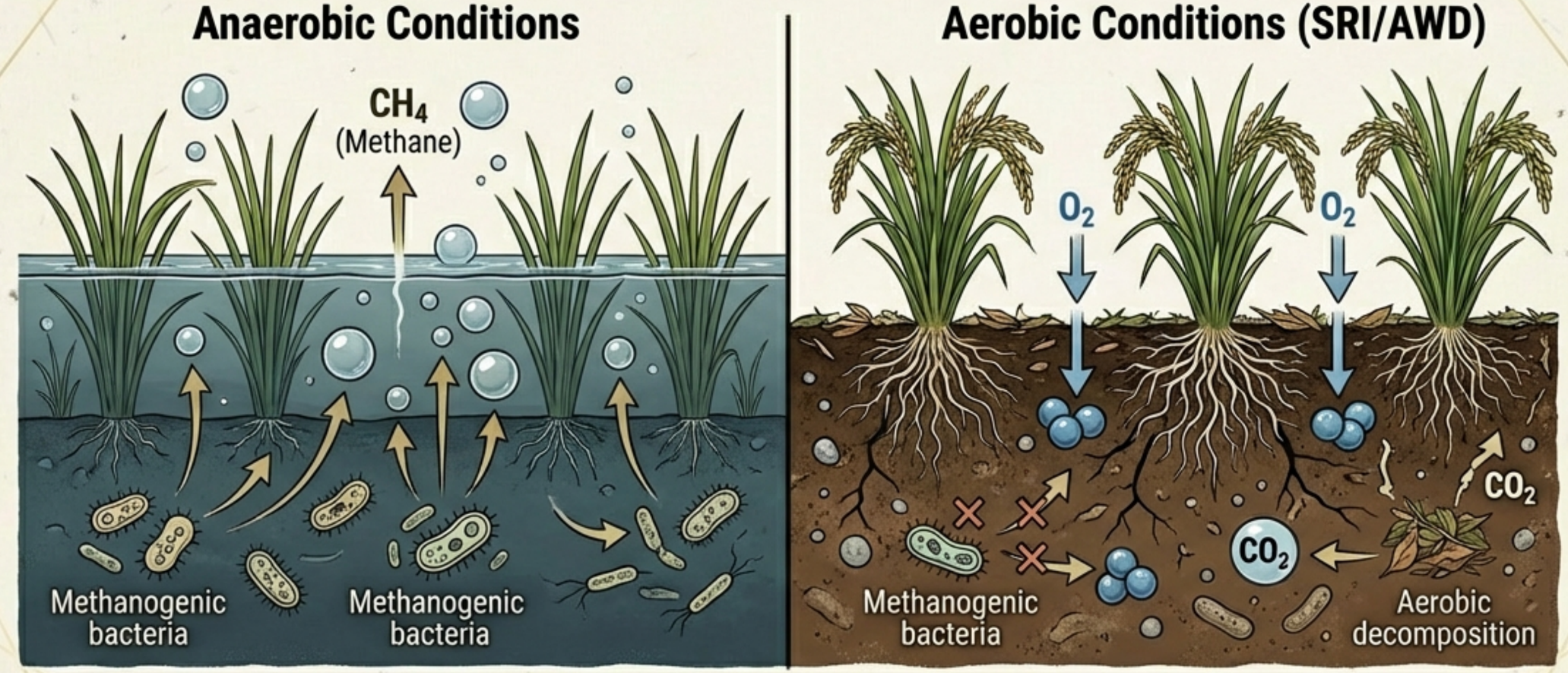
The Nitrogen Lever: Curbing High-GWP Emissions



Legume integration fixes atmospheric N naturally. Closed loops prevent volatilization.

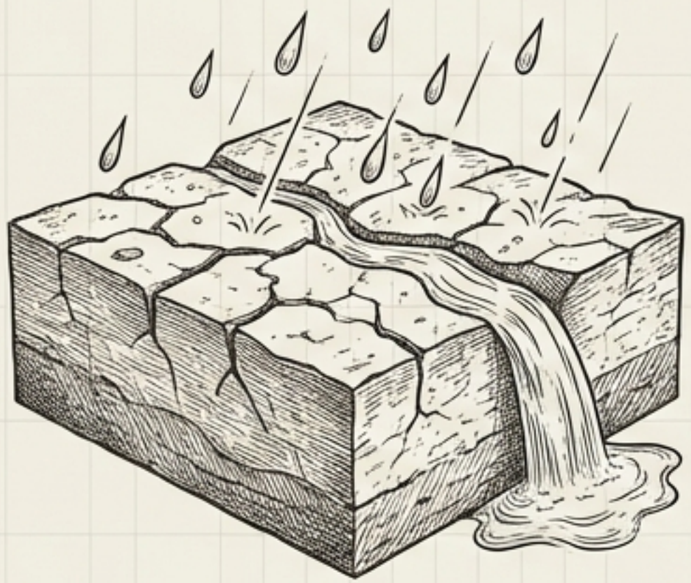
Impact: Drastic reduction in direct field emissions and indirect industrial emissions.

The Methane Lever: Aerobic vs. Anaerobic Rice Systems



Reducing ponding water (AWD) is a potent GHG mitigation strategy, not just a water-saving measure.

Adaptation Strategy: Soil as Water Infrastructure



Low SOC (<0.5%). Water runs off.

The Sponge Effect

1% SOC increase = +150,000 Liters water storage/ha.

High SOC (>1%). Water infiltrates.

Drought Resilience

+7-10 days of crop water availability.

Flood Resilience

Reduced runoff and groundwater recharge.

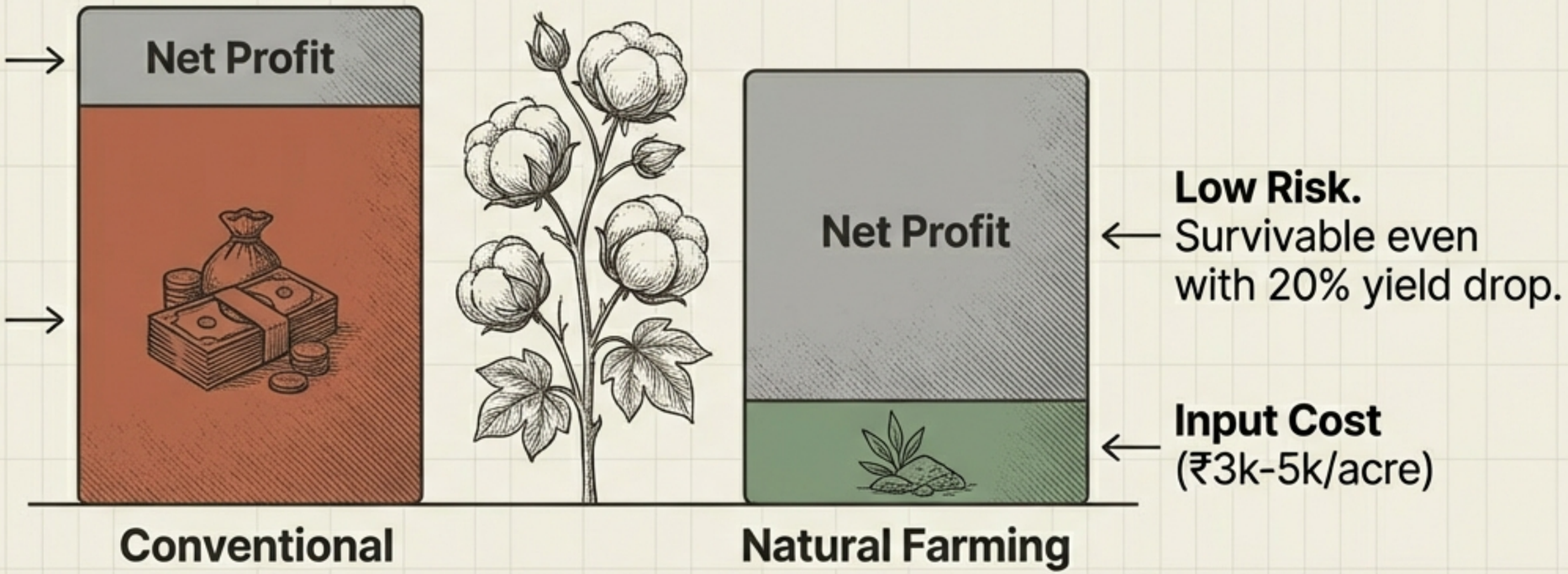
Case Study: Anantapur Natural Farming (2018 Drought)

Conventional fields failed. Natural fields yielded **40-60%** of normal due to moisture retention.

Economic Resilience: The Input-Output Flip

Decoupling production from fixed costs.

Vidarbha Cotton Economics



Moving from 'High Risk/High Reward' to 'Stable Net Income'.
Telangana natural farmers report 50-70% debt reduction.

Resilience Strategy: Genetic & Spatial Diversity

Spreading risk through diversity.

Monoculture

Polyculture

Maize

Pigeon Pea

Intercrop

If one fails, others survive.

Genetic

Local varieties (e.g., Bundelkhand wheat) withstand **42-44°C**.

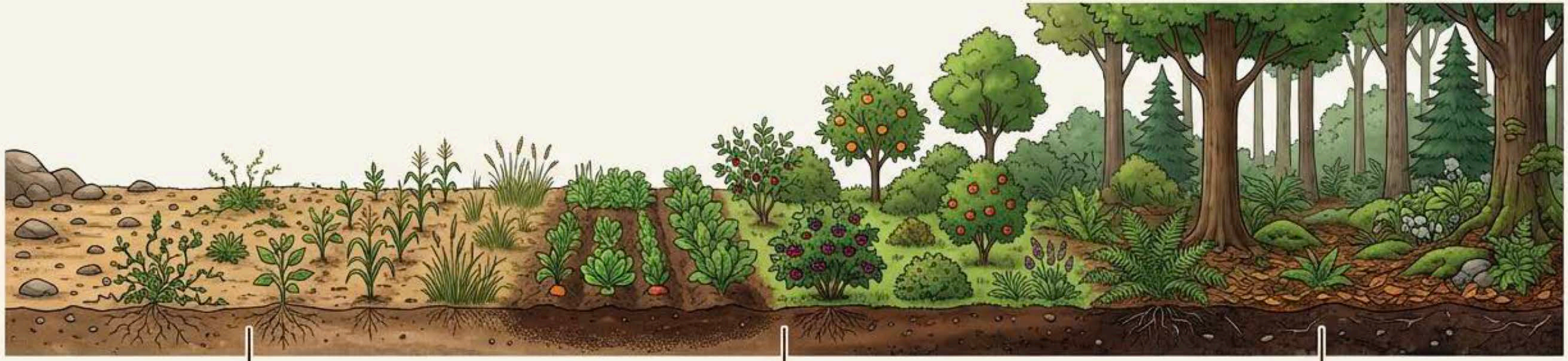
Spatial

Intercropping creates microclimates.

Kerala multi-tier systems: **3-5°C** lower ground temp during heat waves.

The Biological Transition: Mimicking Ecological Succession

Bacterial Dominated | **1:1 Fungi:Bacteria** | **Fungal Dominated**



Annual Weeds/Crops | Vegetables & Shrubs | Old Growth Forests / Perennials

Transition Pathways

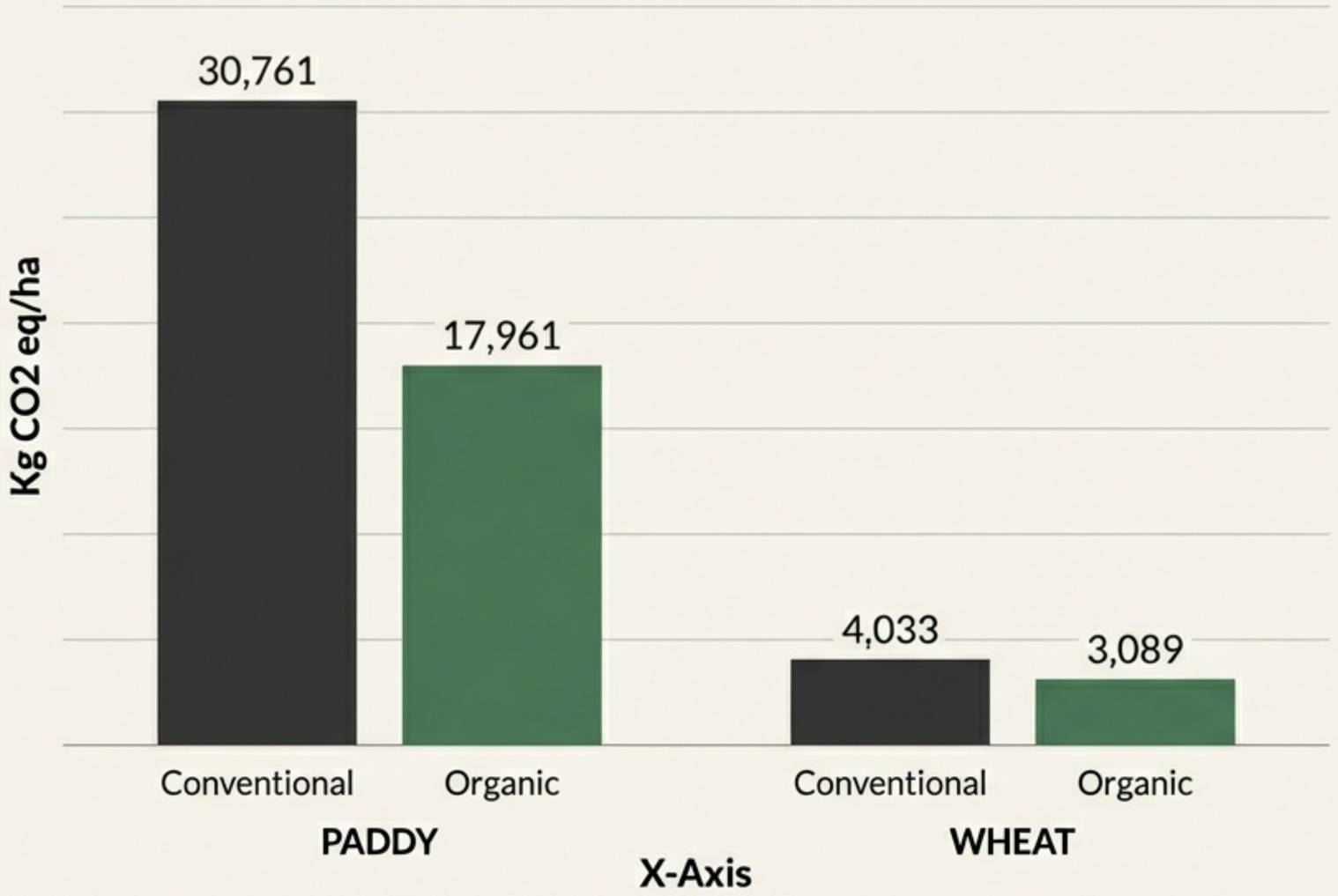
Minimal Tillage

Continuous Soil Cover (Mulch)

Polycrops & Multilayer Farming

The Emissions Reality Check: Conventional vs. Organic.

Total Kg CO2 equivalent per hectare.



Key Insights:

- Paddy Methane drops from 20,223 (Conv) to 12,580 (Org).
- Fertilizer Production emissions drop near zero in Organic systems.
- Shifting practices drastically reduces the Carbon Footprint.

Co-Benefits: Wins for the Farmer, Wins for Society.

ACTION	FARMER BENEFIT	SOCIETAL BENEFIT
Wetland Rewetting	Productive use of wetlands, fisheries.	Flood regulation, improved water quality.
Agroforestry	Diversification protects against single crop failure.	Biodiversity boost, microclimate improvement.
Nutrient Management	Lower input costs (fertilizer/energy).	Decreased nutrient runoff, cleaner waterways.

The Policy Trap: How Subsidies Fuel the Crisis

Node 1

Subsidies Linked to Land Ownership

Support systems target landowners, often leaving tenant cultivators unsupported.

Encourages...

Node 2

High Input Agriculture

Incentivizes excessive use of agrochemicals, energy, and water.

Results in...

Node 3

Environmental Degradation

Soil degradation, declining water tables, and increased emissions.

Current subsidy mechanisms are inadvertently financing the aggravation of the climate problem.

The Invisible Balance Sheet

Paid Market Goods

Deep Soil Charcoal
Food, Fiber, Fuel

Unpaid Ecosystem Services

- Carbon Sequestration
- Water Purification
- Biodiversity Habitat
- Soil Formation
- Pollinator Support

Market Failure

Current markets penalize farmers for providing public goods. A farmer building soil health bears the cost, while society reaps the benefit of climate regulation.

The New Economic Equation: Monetizing Ecosystem Services.

OLD MODEL: Income = (Yield × Price)

NEW MODEL: Income = (Yield × Price) + **ECOSYSTEM SERVICES**

Carbon Sequestration

Water Conservation

Ecological Farming

Farmers become stewards of the environment, creating a diversified income stream resilient to climate shocks.

Monetizing Resilience: Pathways to Green Finance

Green Premium
(Certified Sustainably Grown)

Payments for Ecosystem Services (PES) -
Water/Biodiversity

Carbon Credits
(SOC/Methane Reduction)

Core Crop Revenue

Definitions

Carbon & Green Credits: Tradable certificates for GHG reductions.

PES: Direct incentives for outcomes (e.g., watershed protection).

Strategy Note:

The Goal: Stack these credits to create a revenue stream that funds the transition.

Market Reality: Barriers to Entry

MRV Costs

Measurement & Verification can cost ₹10k-30k/ha, often consuming all potential profit for smallholders.

Aggregation

Buyers need volume. Smallholders (0.5-2 ha) must aggregate via FPOs to participate effectively.

Equity

Risk of excluding tenant farmers and those without clear land titles.

Strategic Insight: Carbon markets are supplements, not substitutes for public policy. They cannot solve structural issues like land tenure.

Carbon Financing: A Menu of Market Opportunities.

Current Carbon Credit Price: ~$10 USD

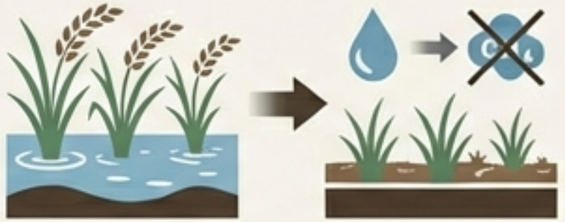
SOIL HEALTH

0.1% Increase in Soil Organic Carbon (SOC)

3 Credits / Acre

~$30

RICE MANAGEMENT



Ponding rice to AWD/SRI (Reducing Methane)

5 Credits / Acre

~$50

AGROFORESTRY

50 Trees per year (e.g., Mango, 3-8 years old)

1 Credit

~$10

Carbon markets provide a tangible mechanism to pay farmers for sustainable practices.

Financing the Transition

Sources

Subsidy Savings
(30% less fertilizer = ₹45,000 Cr).

International Finance
(Green Climate Fund).

Corporate ESG / CSR.

Destination

Soil Health & Ecosystem Service Payments.

Fiscal Neutrality: Reallocating existing funds creates climate impact without exploding the deficit.

Policy Reform: From Input Subsidies to Ecosystem Incentives

Current Subsidy Spend:
₹2-3 Lakh Crores
(incentivizing overuse)

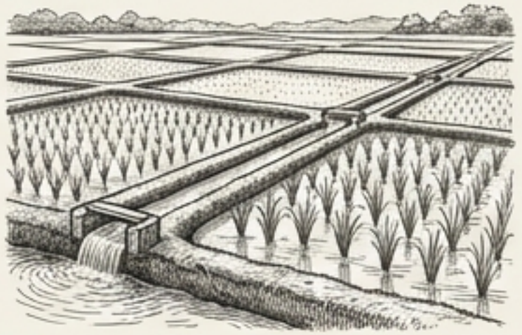
The Climate-Smart Subsidy Framework

1. Soil Health Incentives

Pay farmers per % increase in SOC (e.g., ₹5k-10k/ha)

2. Input Reduction Rewards

Direct payments for reducing synthetic fertilizer use



3. Water-Smart Rice Rewards

Incentives for adopting AWD/SRI to save water and reduce methane

Shifting the budget from funding destruction to funding regeneration

Policy Support: The PM PRANAAM Initiative

Incentivizing States to reduce chemical fertilizer usage

The government is pivoting from subsidizing pollution to incentivizing sustainability. PM PRANAAM grants go to districts and villages to reward reduced chemical inputs.

15.14 Lakh Tonnes

Total Fertilizer Reduction (2023-24)

₹3,156 Crore

Subsidy Reduction Achieved

₹1,578 Crore

Incentives Passed to States (50% of savings)

Leading States: Karnataka, Maharashtra, West Bengal, Andhra Pradesh

Recommendations: Scaling the Solution.

1 Decouple from Land Ownership

Ensure all support systems and ecosystem payments reach the *cultivator*, including tenant farmers, rather than just the landowner.

2 Direct Income Support

Transition from input-based subsidies to Direct Benefit Transfer (DBT) linked to verified ecosystem services.

3 Local Grants

Direct grants to districts and villages to empower local decision-making and community-led resource management.

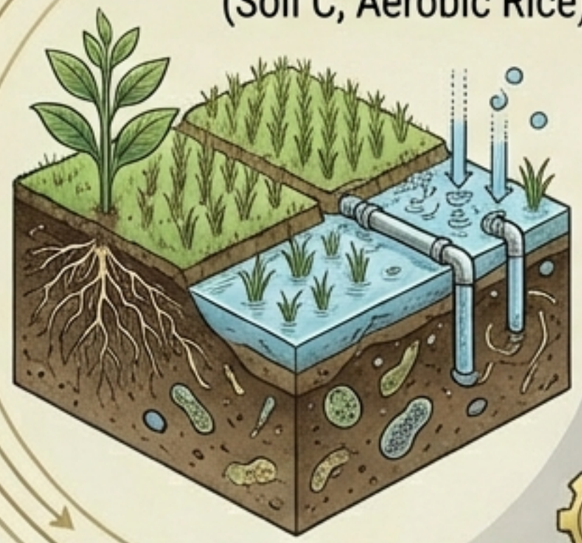
4 Default Organic Areas

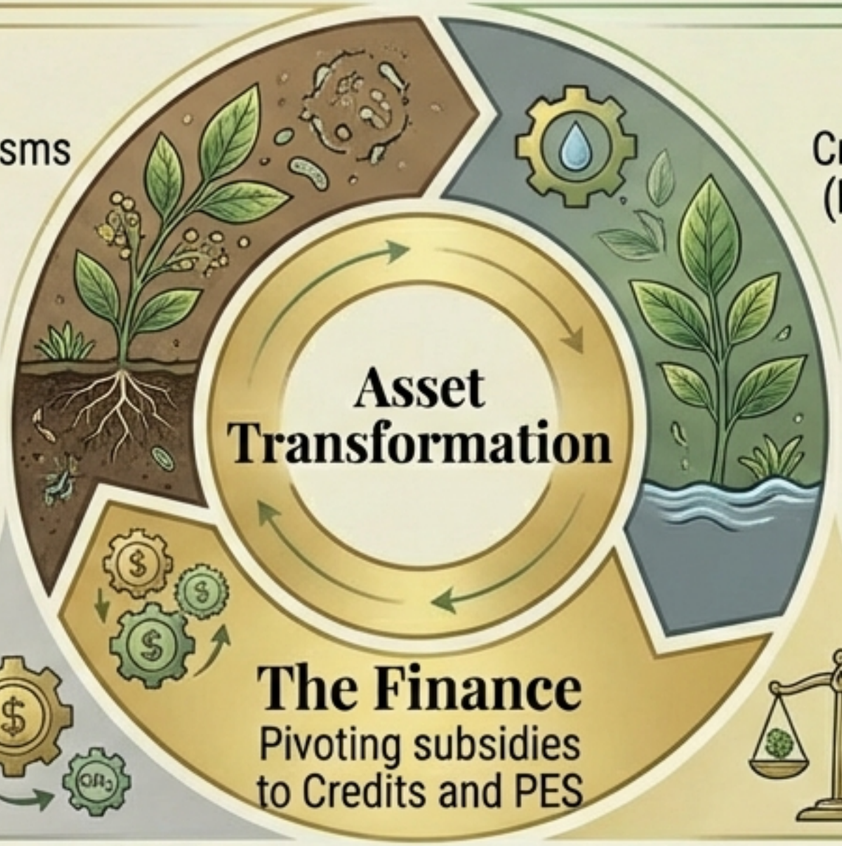
Create mechanisms to automatically apply incentives to regions that are already organic by default.

Conclusion: A Unified Strategy for Climate and Agriculture

The Science

Proven mitigation mechanisms
(Soil C, Aerobic Rice)





The Value

Critical ecosystem services
(Resilience, Water Security)

The transition requires treating farmers not just as producers of food, but as stewards of the planetary systems on which our economy depends.