मृदा विज्ञान एवं कृषि रसायन विज्ञान संभाग, भा. कृ. अनु. प. - भा. कृ. अ. सं., नई दिल्ली

Improving Soil Organic Carbon in Indian soils

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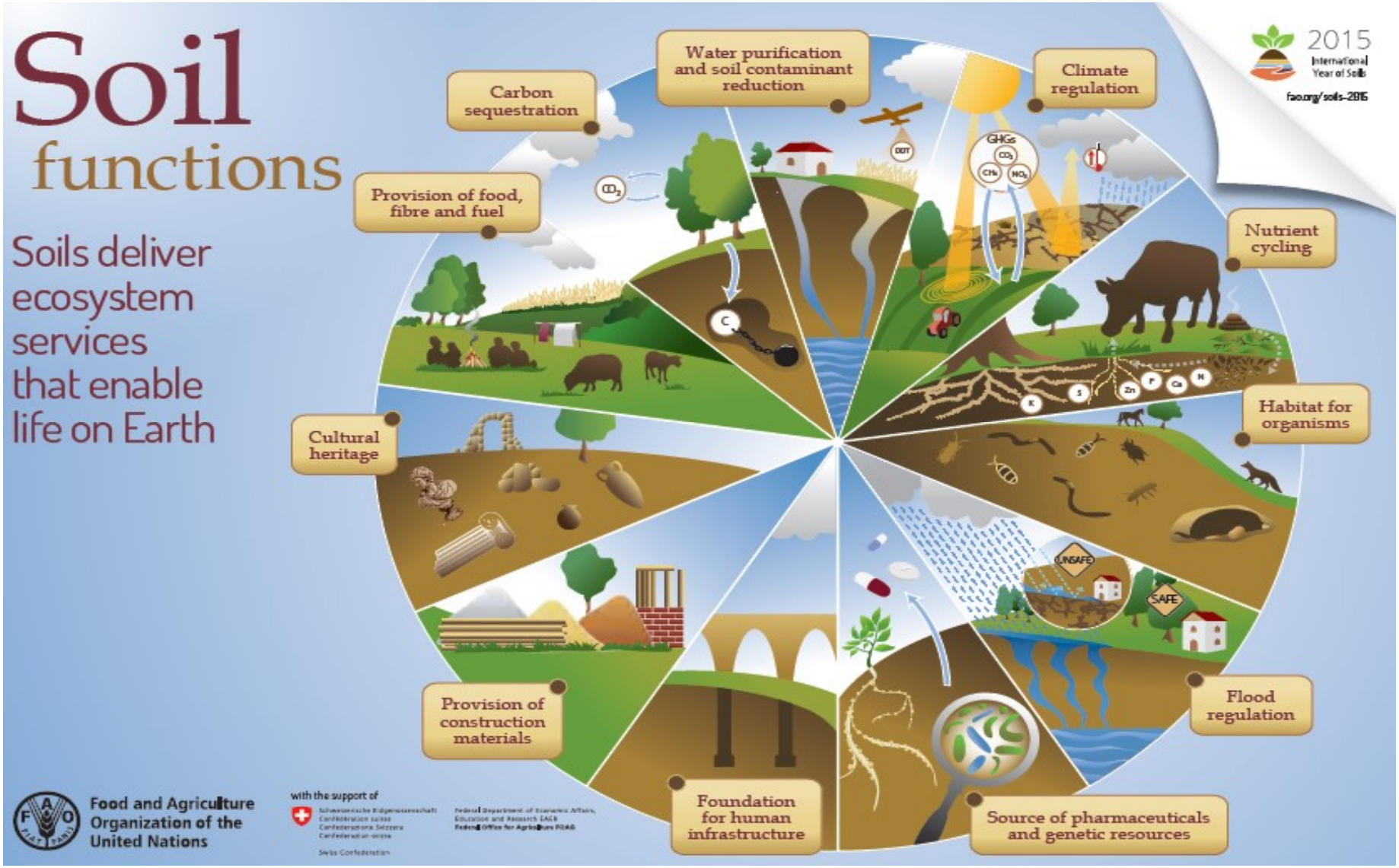
Functions of soil



(FAO 2015)

Major soil biological indicators and related soil processes

Indicator	Processes and soil functions
Soil organic matter	Structural formation, mineralization, biomass carbon, nutrient retention
Earthworm population and other soil, macro fauna and activity	Nutrient cycling, organic matter decomposition, formation of soil structure
Soil biomass carbon	Microbial transformations and respiration, formation of soil structure and organo-mineral complexes
Total soil organic carbon	Soil nutrient source and sink, bio-mass carbon, soil respiration and gaseous fluxes
Potentially mineralizable N	It is measure soil N supllying capacity and also surrogate measure of microbial biomass and labile fraction of soil organic matter
Soil enyzmes activity	It is often closely related to soil organic matter, microbial activity and microbial biomass
Metabolic quotient	Physiologically , thise index describe the substrate mineralized per unit of microbial biomass carbon

Lal *et al.* (1994)

NPK fertility status of soils

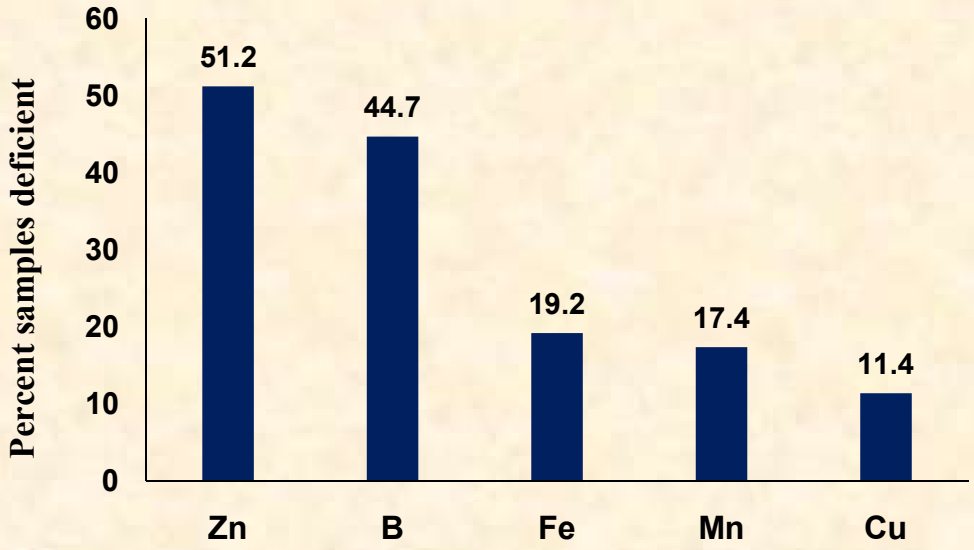
Nutrient	% Districts in different fertility classes		
	Low	Medium	High
Nitrogen	59	36	5
Phosphorus	49	45	6
Potassium	9	39	52

Muralidharudu et al. (2011)

Use efficiency of applied nutrients

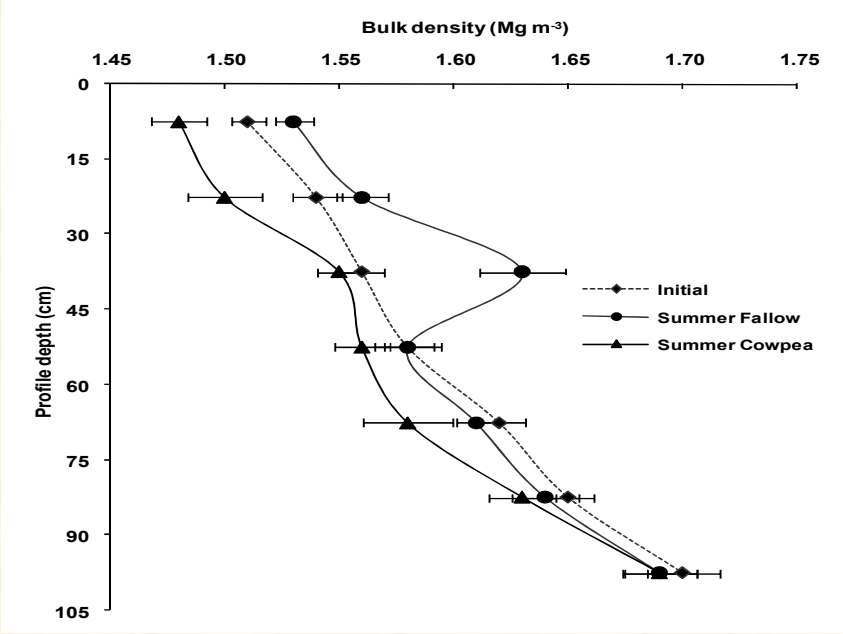
Nutrient	NUE (%)
Nitrogen	30-50
Phosphorus	15-20
Potassium	70-80
Sulphur	20-25
Micronutrients	2-5

Secondary and micronutrient deficiency in soils



Shukla et al. (2021)

Sub-surface compaction under R-W system



Dwivedi et al. (2003)

Causes of soil health deterioration

- Inadequate and unbalanced fertilizer use
- Incomplete fertilizer prescriptions
- Poor soil testing services
- Low use of organics
- Clean cultivation – residue removed/burnt
- Excessive tillage; poor land leveling
- Ignoring principles of crop rotation – monoculture
- Lack of awareness among farmers
- Unavailability of right fertilizers at right time

Soil health

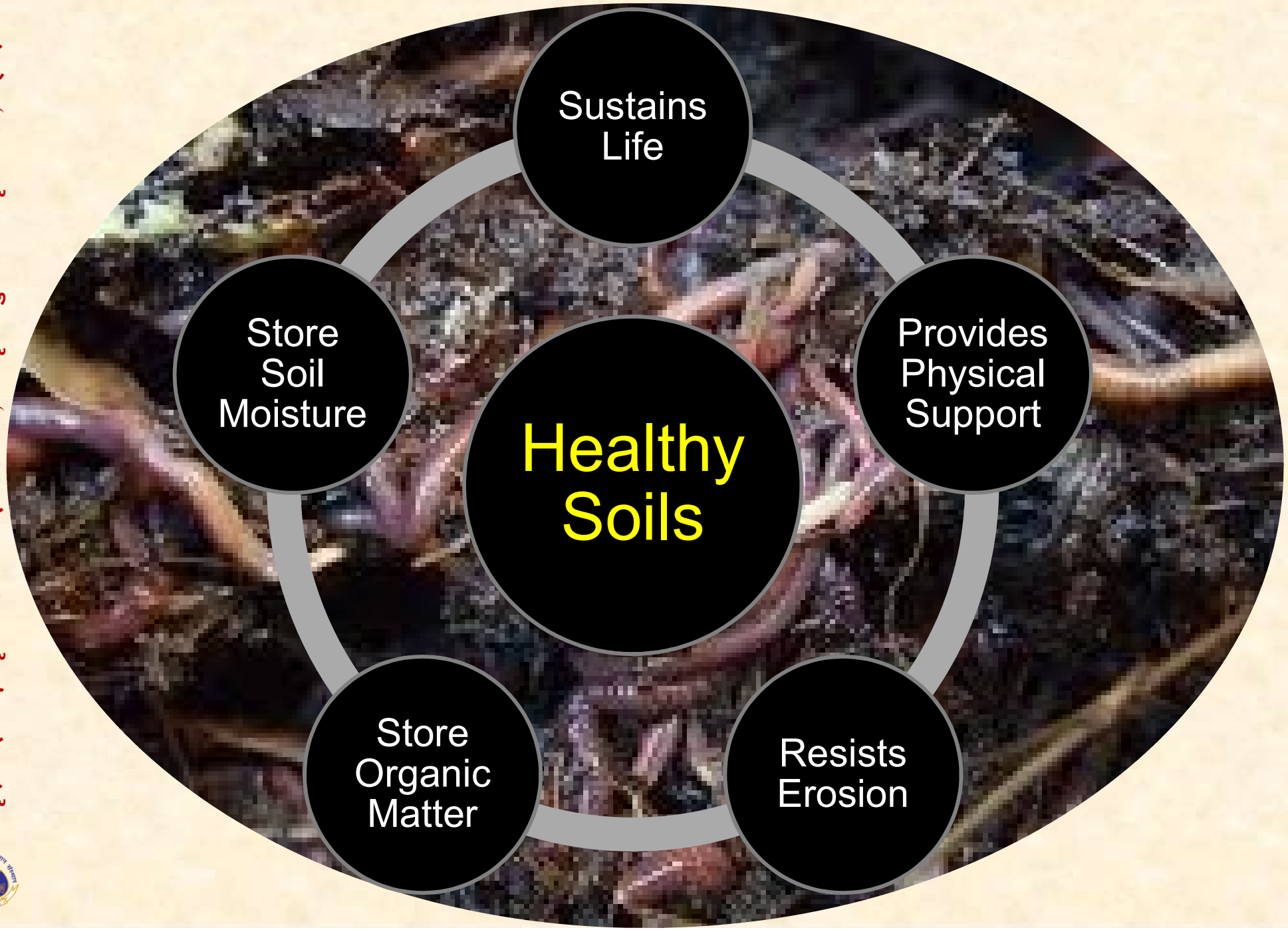
Capacity of a living soil to

- function within a natural or managed ecosystem,
- sustain plant and animal productivity,
- maintain or enhance water and air quality,
- promote plant and animal health

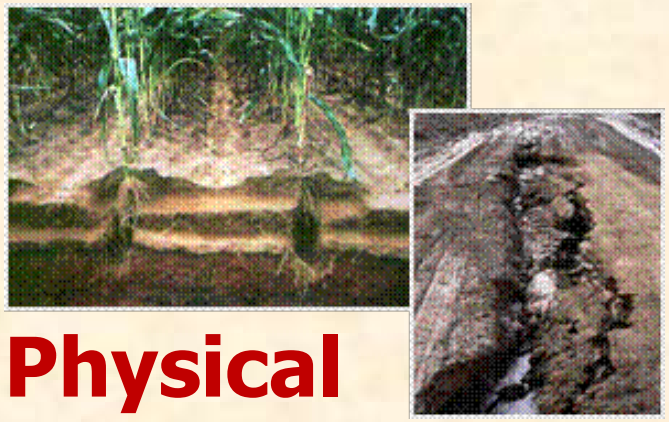
(Doran, 2002)

- Soil quality denotes soil's usefulness for a particular purpose over a long time scale.

Dynamics of Healthy Soils



Soil health indicators

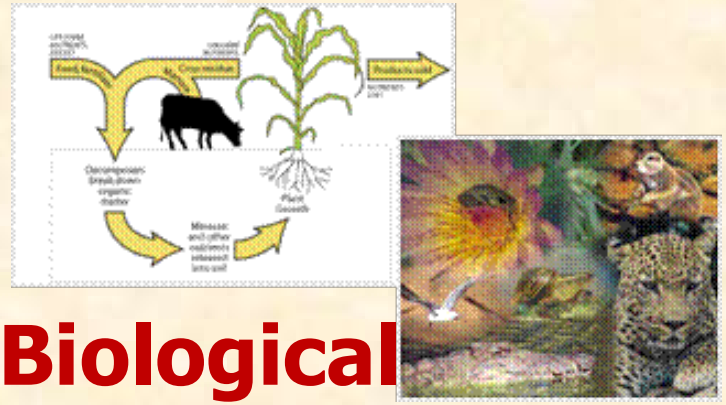


Physical

- Water retention & availability
- Root growth
- Erosion
- Compaction

Chemical

- Cation exchange capacity
- Nutrient retention
- Nutrient reserves
- Buffering
- Bioavailability of pollutants



Biological

- Soil organic C
- Biodiversity
- Nutrient cycling
- Degradation-disease
- Trace gas emissions

Safe | Nutrient rich | Diversified | Adequate | Stable | Resilient

Sustainable Food **Production**

Food & Nutrition Security

HEALTHY SOILS

Foundation of

Contributing

Compromise

Soil threats

Soil moisture depletion | Soil erosion | Loss of organic matter | Nutrients depletion | Reduction of soil biodiversity | Salinization | Acidification | Soil contamination | Soil sealing | Soil compaction

Climate change | Unsustainable soil management | Land-use changes

Emerging multi-nutrient deficiencies in Indian soils

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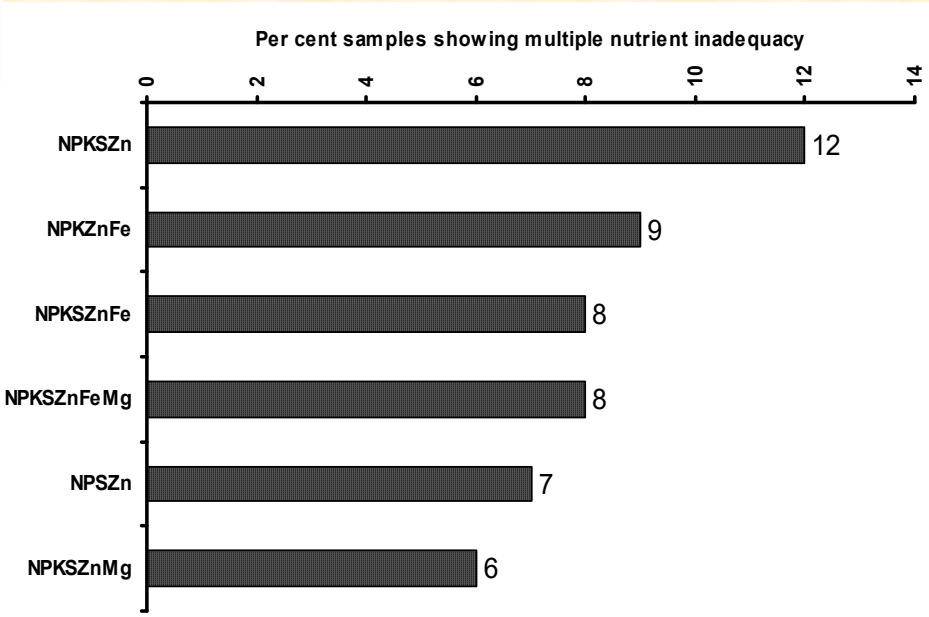
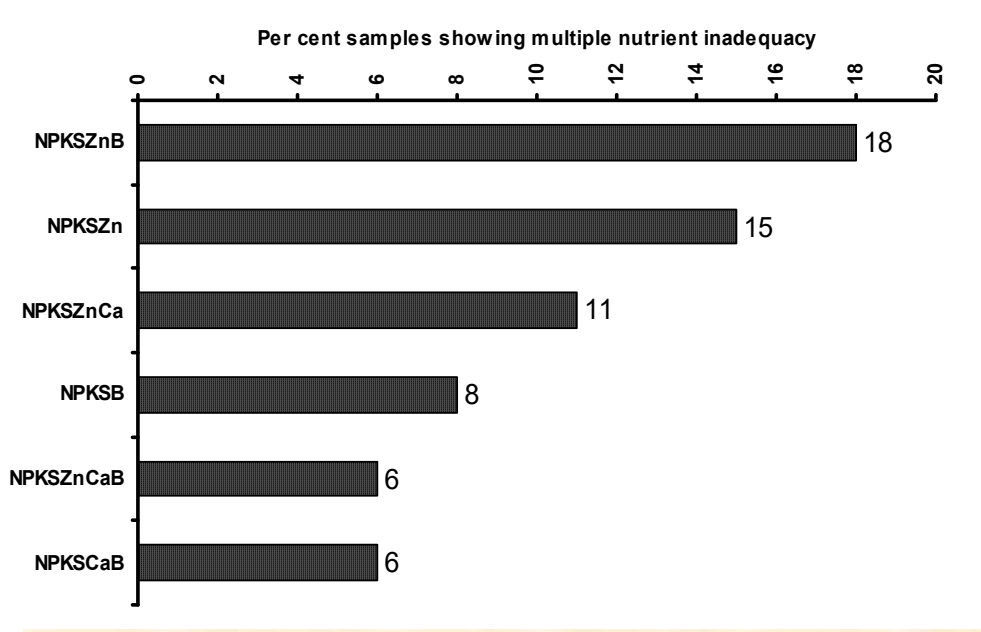
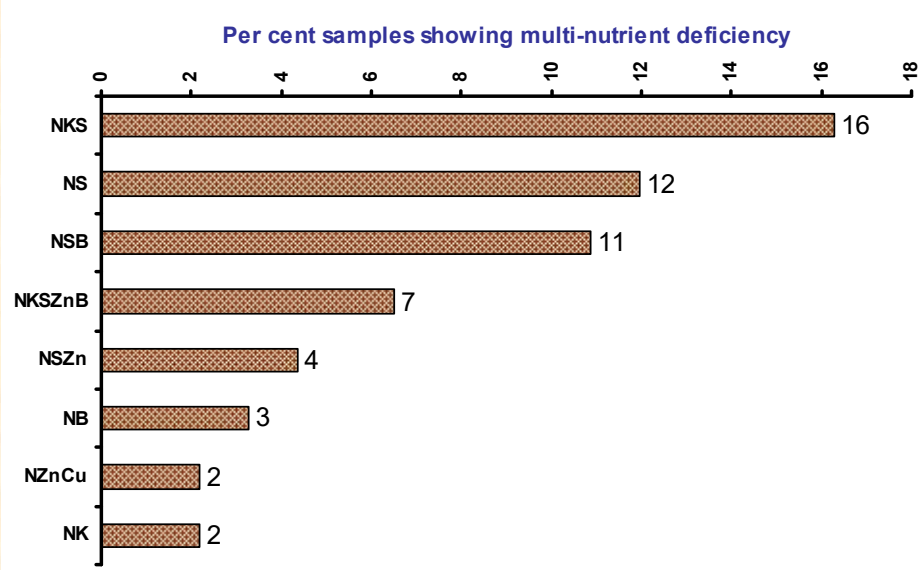
Year	1950	1960	1970	1980	1990	2000	2010	2020
	N	N	N	N	N	N	N	N
		Fe	Fe	Fe	Fe	Fe	Fe	Fe
			P	P	P	P	P	P
			Zn	Zn	Zn	Zn	Zn	Zn
			K	K	K	K	K	K
				S	S	S	S	S
				Mn	Mn	Mn	Mn	Mn
					B	B	B	B
						?	Mg	Mg
								Ca, Mo?



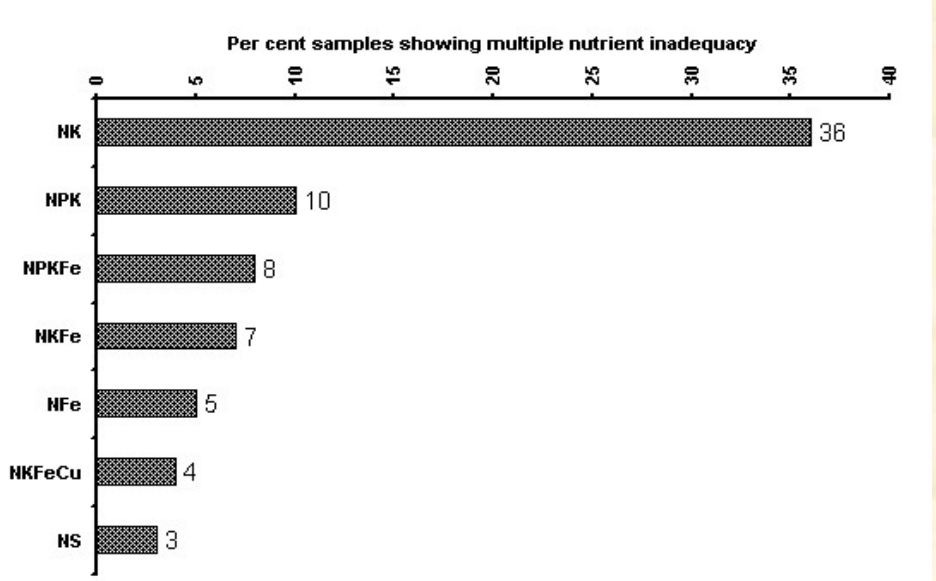
Marusthali (AESR 2.1; Birawas; Jodhpur)



Chhotanagpur Plateau (AESR 12.3; Barhu; Ranchi)



North Punjab Plain & Ganga-Yamuna Doab (Lohtaki : Gurgaon)



Rajasthan Bagar & North Gujrat Plain (AESR 2.3; Deesa; Banaskantha)

Multi-nutrient deficiency in soils of different agro-ecological sub-regions (AESRs)


-K


- P


-S


-Zn

Boron deficiency on vegetables

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This Article is From Mar 26, 2022

India's Soil Organic Carbon Content Fell From 1% To 0.3% In 70 Years: Report

Soil Organic Carbon is the main component of the soil organic matter and gives soil its water-retention capacity, structure, and fertility, he told reporters in Nagpur, Maharashtra, on Friday evening.

Press Trust of India | India News | Mar 26, 2022 15:27 pm IST

Read Time: 3 mins

Share

Current Status

Aspect	Value/Status
SOC in 1950s	~1%
SOC in 2020s	0.3–0.4%
Healthy SOC threshold	1–1.5%
SOC stock (0–30 cm)	9.6 Pg
SOC stock (0–150 cm)	29.9 Pg
Regions most affected	Arid/semi-arid, intensive agriculture
Restoration strategies	Organic amendments, conservation tillage, crop rotation

NBSS&LUP (2022)

Organic and inorganic carbon stock in Indian soils (0-0.3 m soil depth) (Values in Pg)*

Soil Carbon	Alluvial soils	Black soils	Arid soils	Brown forest soils	Red soils	Total Carbon
Organic	2.79	2.56	0.71	0.12	3.33	9.55
Inorganic	1.52	1.08	1.39	0.00	0.15	4.14
Total	4.30	3.64	2.11	0.12	3.52	13.69

*Source : Bhattacharyya *et al.* (2005)

Soil organic matter/carbon- *soul of soil*

- An index of N availability
- A soil conditioner & nutrient source
- Substrate for microbial activity
- Influences CEC
- Complexes the heavy/toxic metals
- Contents decrease with decreasing moisture & increasing temperature

Contd..

Contd…(SOM)

- **Soils of India have low OM content**
- **Increase in OM content beyond a particular point not possible**
- **Contents decrease with decreasing moisture and increasing temperature**
- **Despite the limitations, improving SOM is crucial for sustaining soil health**

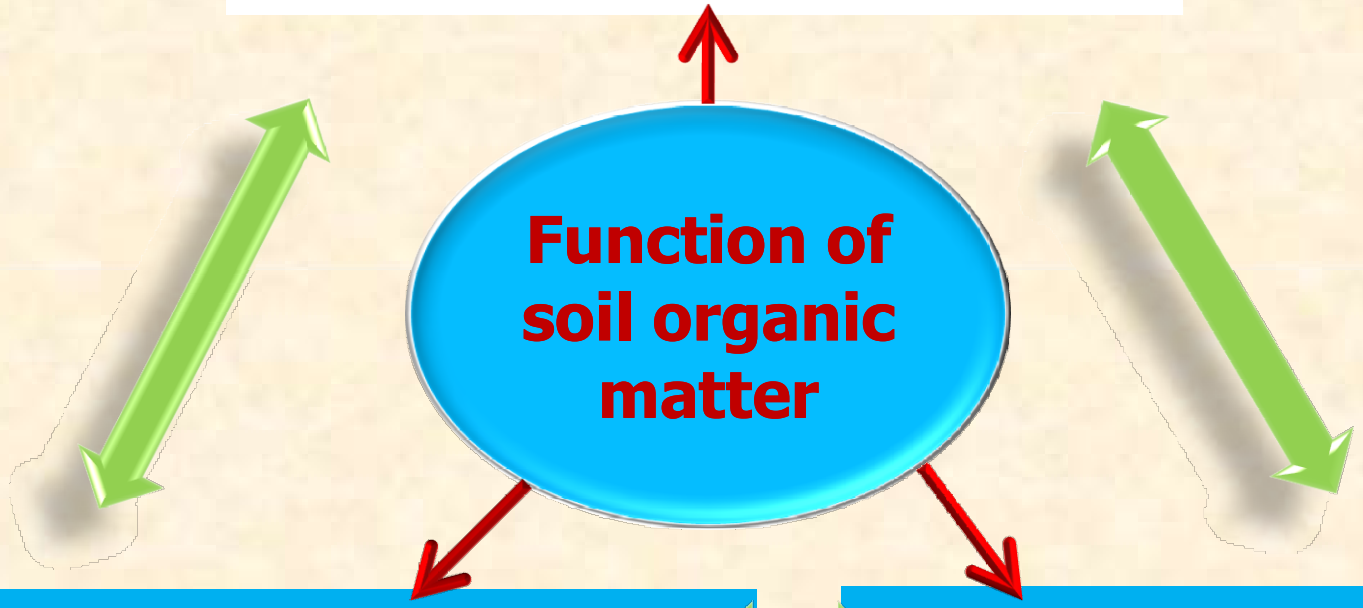
Steps to Improve Indian soil organic carbon

- **Use of organic matter inputs:**
  Incorporating compost, green manure and bio-fertilizers can increase SOC levels.
- **Balanced nutrient management:**
  The Soil testing service promotes integrated nutrient management, advising on the judicious use of chemical fertilizers alongside organic and bio-fertilizers.
- **Improving farming practices:**
  SOC can increase by adopting practices like cover cropping, crop rotation, and reduced tillage.
- **Adopting Conservation Agriculture:**
  Minimal tillage, cover cropping and crop rotation can reduce carbon loss.
- **Better management:**
  Implementing better water management and conservation practices is crucial for retaining soil moisture and organic carbon.
- **Agroforestry and Reforestation:**
- **Farmer Education and Incentives:** Training and incentives to farmers to adopt carbon-friendly practices will ensure widespread implementation.

Role of Soil Carbon

Biological functions

- Provides energy to biological processes
- Provides nutrients (N, P and S)
- Contribute to the resilience



Physical functions

- Improve the structural stability of soils
- Influence water retention properties
- Alters soil thermal properties

Chemical functions

- Contribute to cation exchange capacity
- Enhance pH buffering
- Complexes cations

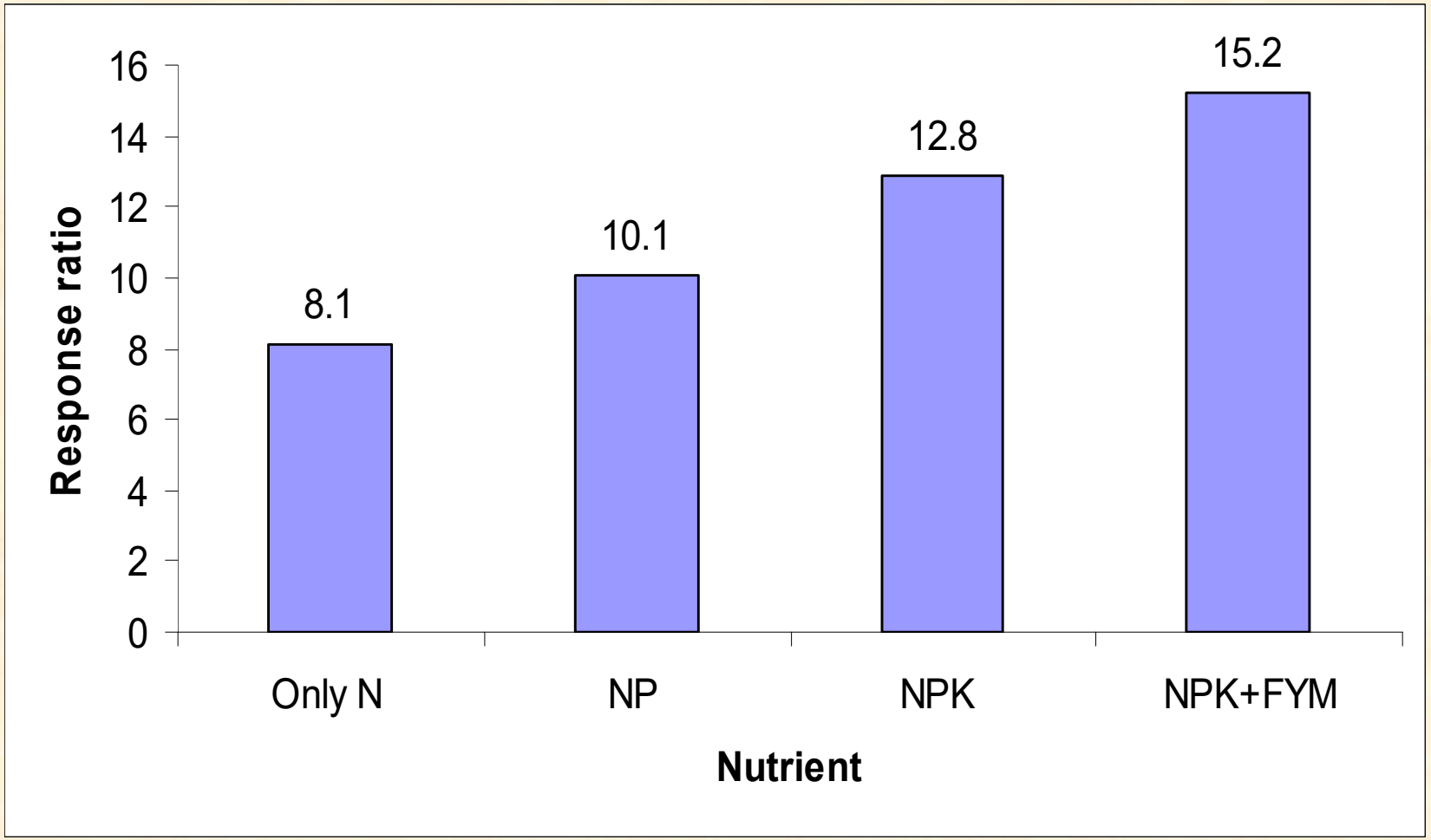
Diverse functions performed by organic matter in soils (GRDC 2009)

Factors affecting organic carbon accumulation in soils

- Climate
- Cropping and Tillage
- Natural Vegetation
- Texture
- Drainage
- Rotations, residues and plant nutrients

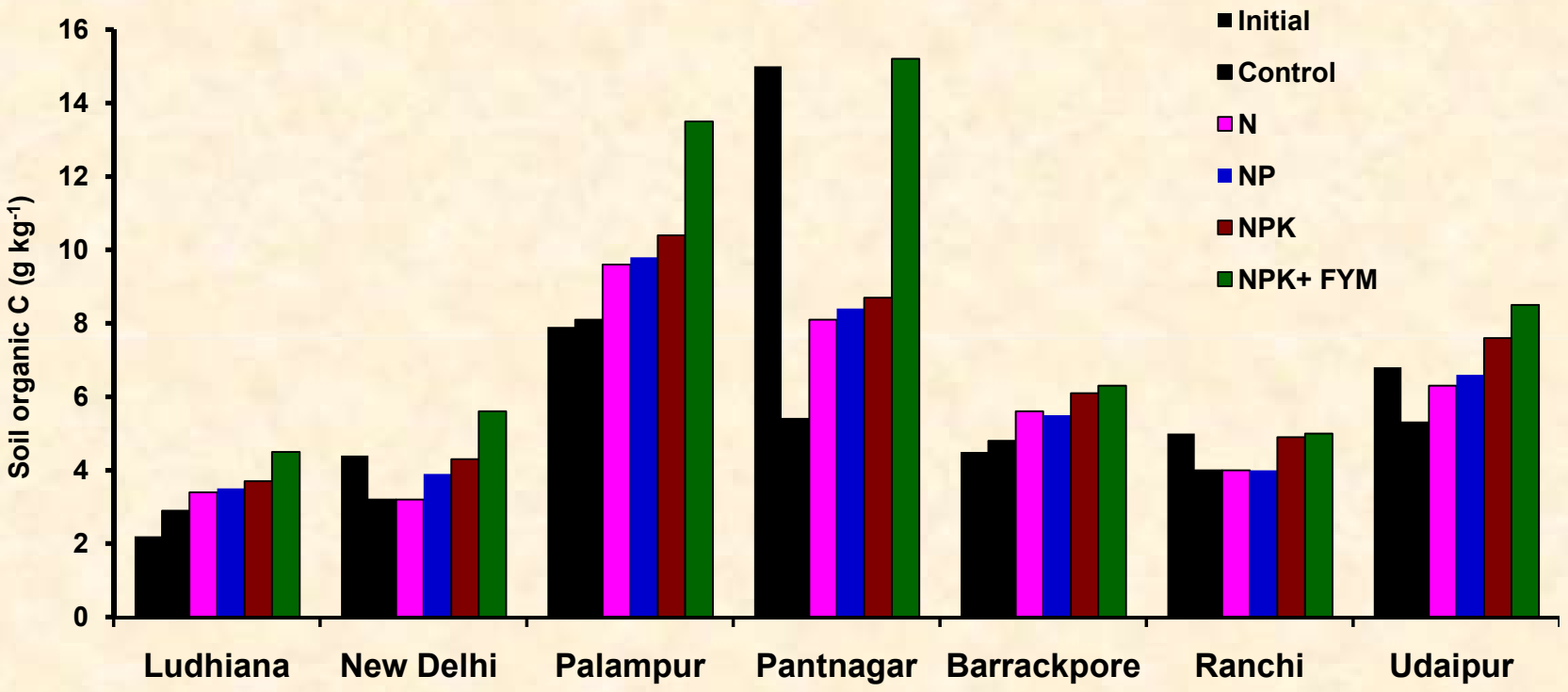
Experiences from LTFEs

Trends in response to fertilizers (kg grain/kg NPK)



Soil Organic Carbon

- Source of life in soil, decides quality of soil health/quality



AICRP-LTFE (2019-20)

Long-term impact of fertilizers on soil organic carbon pools

Treatment	SOC ($Mg\ ha^{-1}$) 1994	SOC ($Mg\ ha^{-1}$) 2003	Changes in SOC ($Mg\ ha^{-1}$)	C sequestration efficiency (%) SOC
NPK	49.0	54.1	5.18	21.0
150% NPK	54.1	63.5	9.36	34.0
NP	47.9	53.0	5.03	22.5
N	47.1	52.0	4.84	23.1
NPK+FYM	**58.3**	**72.1**	**13.8**	17.1
Control	44.9	48.7	3.83	28.5

Soil organic C (SOC), changes in SOC and C sequestration efficiency in 0–45 cm soil layer in a long-term fertilizer experiment

Purakayastha *et al.* (2008)

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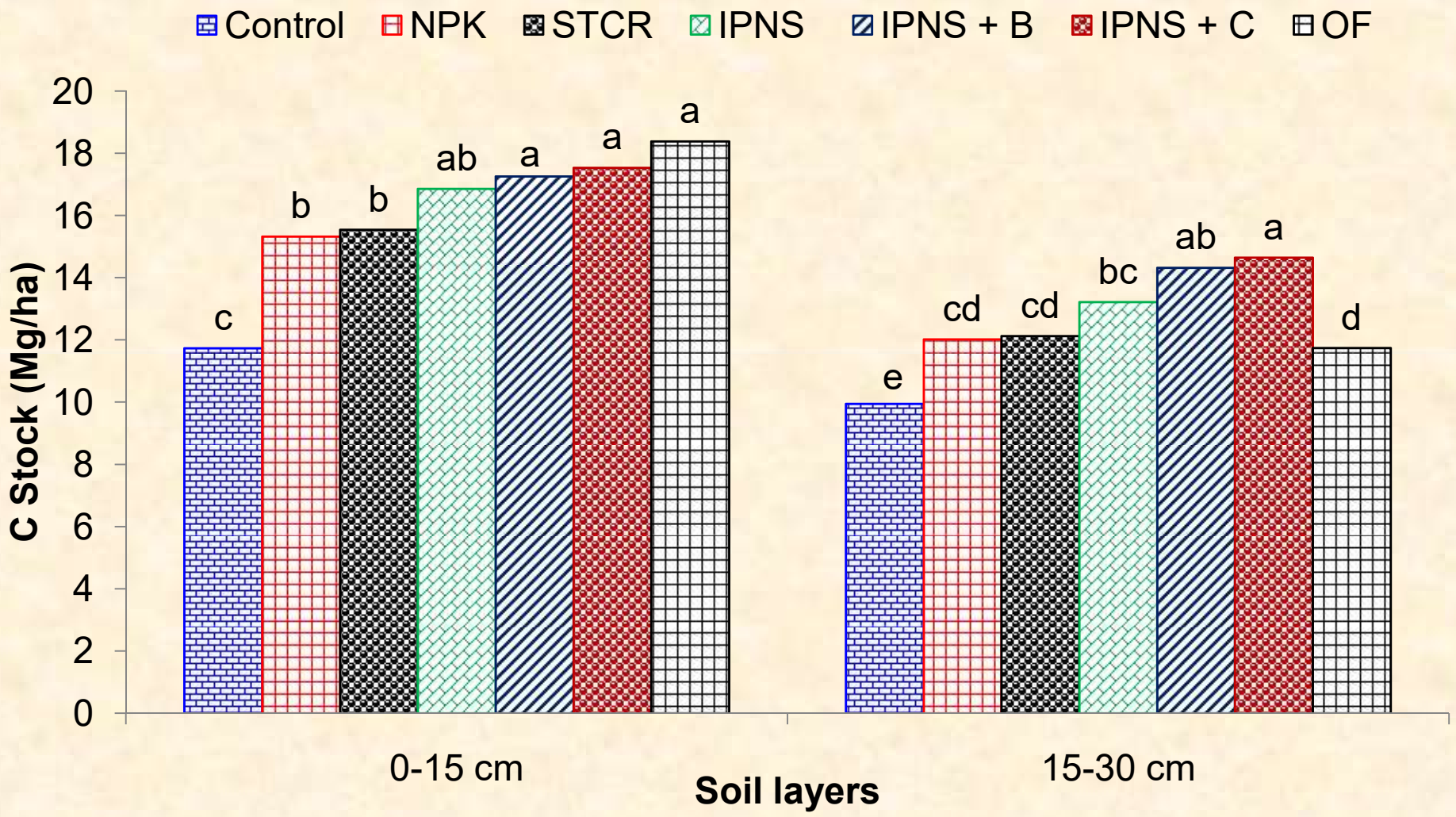
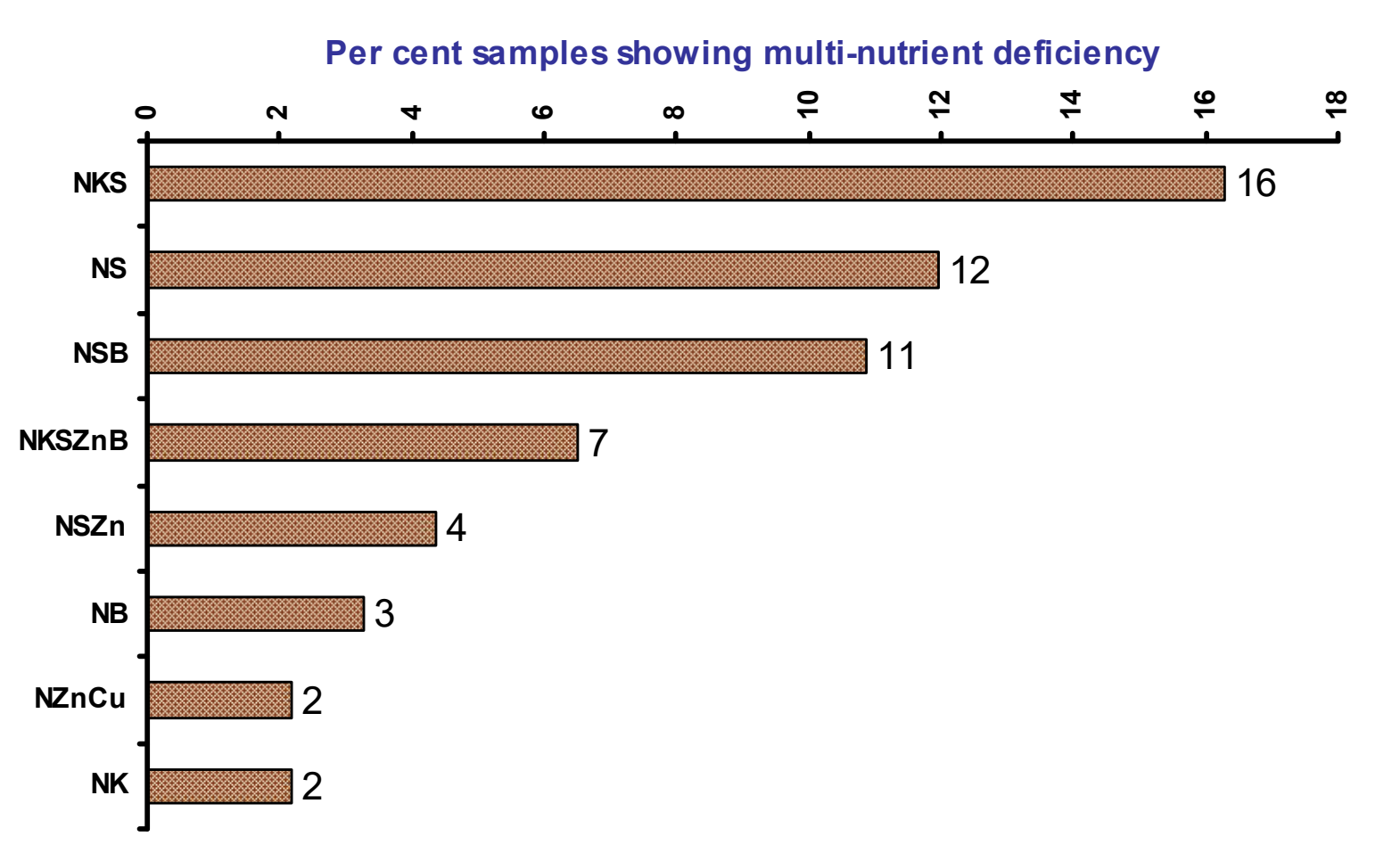
Crop performance under IPNS vs. other fertiliser options (AICRP-LTFE, IARI)

Effect of long-term fertilization on C stock in the 0-15 and 15-30 cm soil layer of rice-wheat system



Meena et al. (2022)

Case study on soil testing & Nutrient Management



Extent of multi-nutrient deficiency in soils of village Lohtaki, Gurgaon

Meena et al., 2023

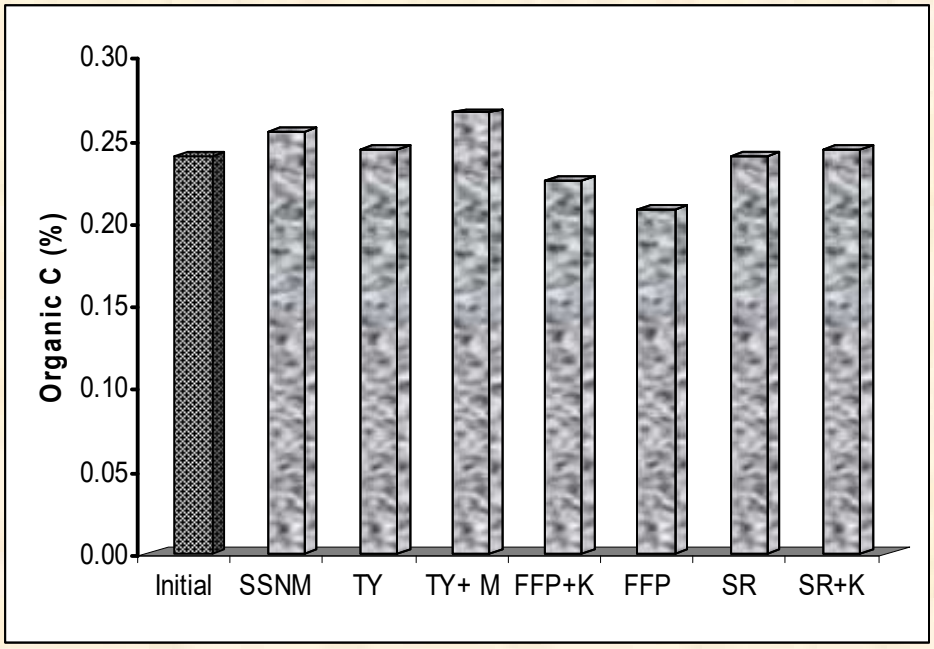
Grain yield of pearlmillet-wheat system under different nutrient supply options

Treatment	Grain yield (t/ha)		
	Pearlmillet	Wheat	PMEY*
SSNM	4.12	5.61	13.69
TY	3.65	4.88	11.97
TY+Micro	3.93	5.27	12.91
SR	3.10	4.03	9.97
SR+K	3.68	4.83	11.92
FFP+K	2.60	3.78	9.05
FFP	2.21	3.40	8.00

*Pearlmillet equivalent yield

Meena et al., 2023

Excellent crop performance under SSNM on farmers' fields



Conservation Agriculture (CA)

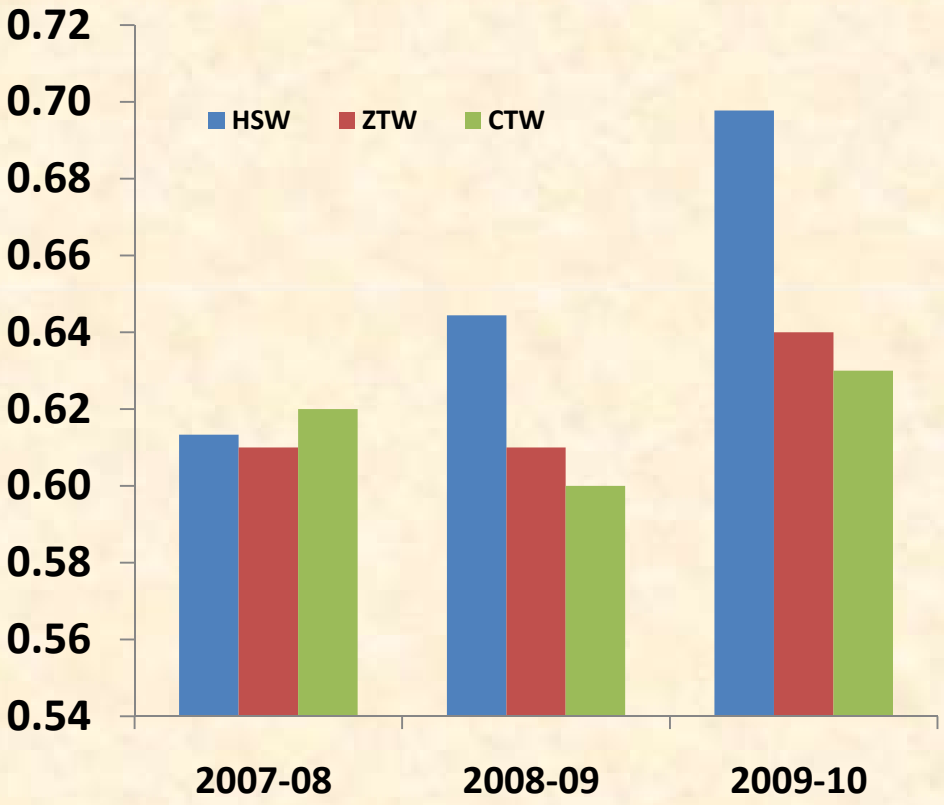
- **Minimum soil disturbance**
  (No-till; reduced till; Permanent raised beds etc.)
- **Crop residue retention on soil surface**
- **Crop diversification**

Field experiment at IARI under CA

Prof. Rattan Lal visited CA experiments

Changes in TOC (%)

HSW: CA with residue
ZTW: CA without residue
CTW: Conventional tillage



Organic carbon content in soil (0-5 cm) after harvest of rice under rice-wheat cropping system

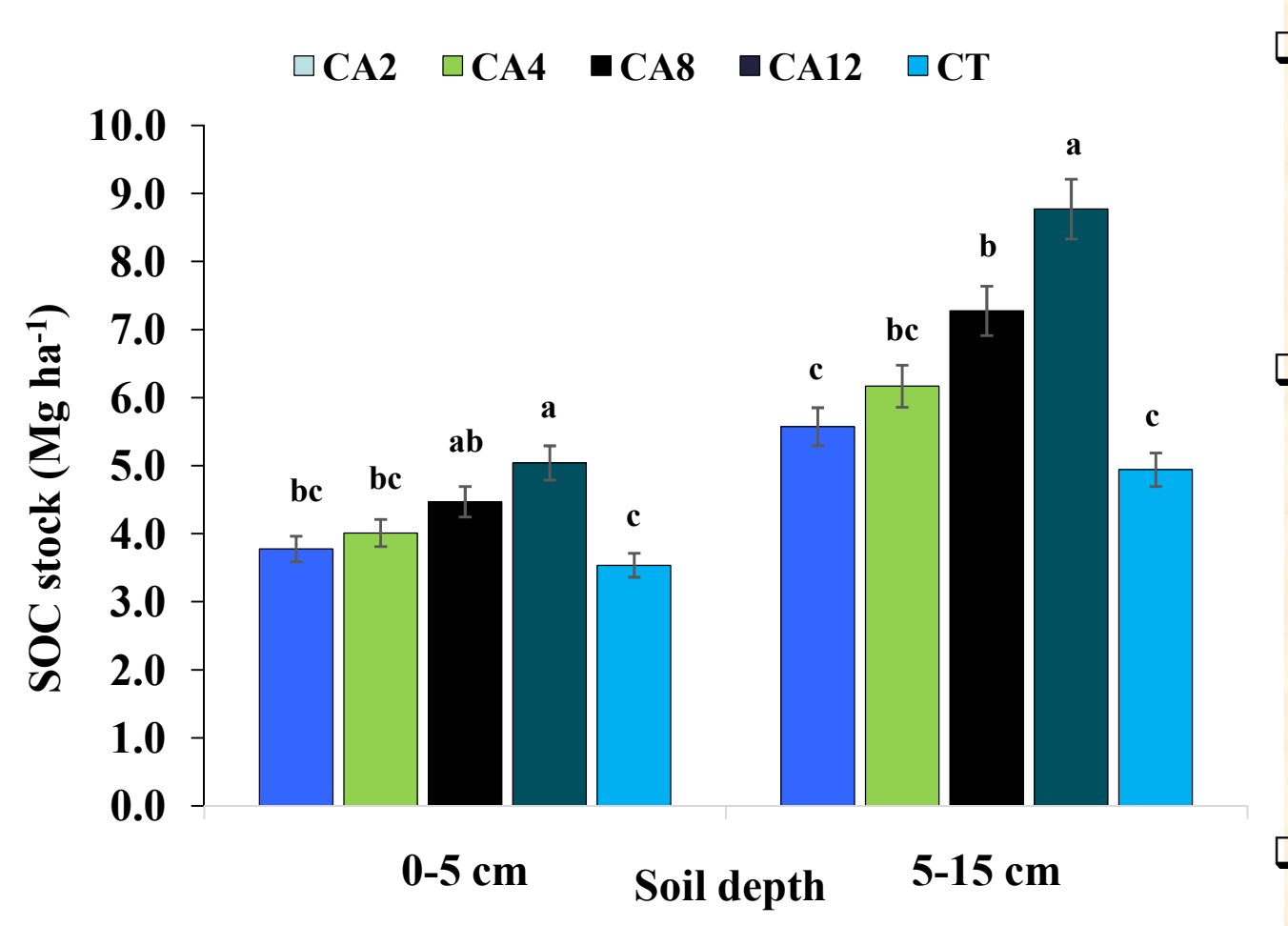
Tillage and crop establishment	WB organic carbon (mg g^{-1})*
DSR - ZTW	6.50
DSR+ MBR-ZTW + RR–SMB	7.50
TPR-ZTW	5.10
TPR-CTW	5.20
LSD (P=0.05)	0.07

Initial value of OC 6.0 mg g^{-1} (0-15 cm); * Walkley and Black C (WBC);

Effect of conservation agriculture on soil C pools and total N after harvest of rice in rice-wheat cropping

Treatment	Very labile C (g kg^{-1})		Total N (g kg^{-1})	
	0-5 cm	5-15 cm	0-5 cm	5-15 cm
DSR - ZTW	1.7b	0.9a	1.02ab	0.72a
MBR+DSR - ZTW + RR –SMB	2.0a	1.1a	1.13a	0.74a
TPR - ZTW	1.7b	0.9a	0.89b	0.70a
TPR-CTW	1.6b	0.9a	0.86b	0.71a

Effect of duration of CA on soil organic carbon stock



Effect of conservation agriculture on SOC stock in 0-5 and 5-15 cm soil depth.

CA2- Conservation agriculture followed for 2 years; CA4- Conservation agriculture followed for 4 years; CA8- Conservation agriculture followed for 8 years; CA12- Conservation agriculture followed for 12 years; CT- Conventional tillage.

- CA has shown a substantial impact on SOC stock at both soil depths.
- The CA12 scenario had 42.3 and 77.5% higher SOC stock over CT at topsoil (0-5 cm) and lower depth (5-15 cm), respectively.
- However, no differences in SOC content and stock in short-term CA over CT were noticed.

Dash & Meena (2025)

Tillage effects on soil (0-2 in.) Properties at Lancaster, Wis.

Tillage	Stab. Aggr.	Total C	Earth Worms
	%	g/kg	No./m^2
No-till	46	24	78
Chisel	34	16	52
Plow	36	11	53

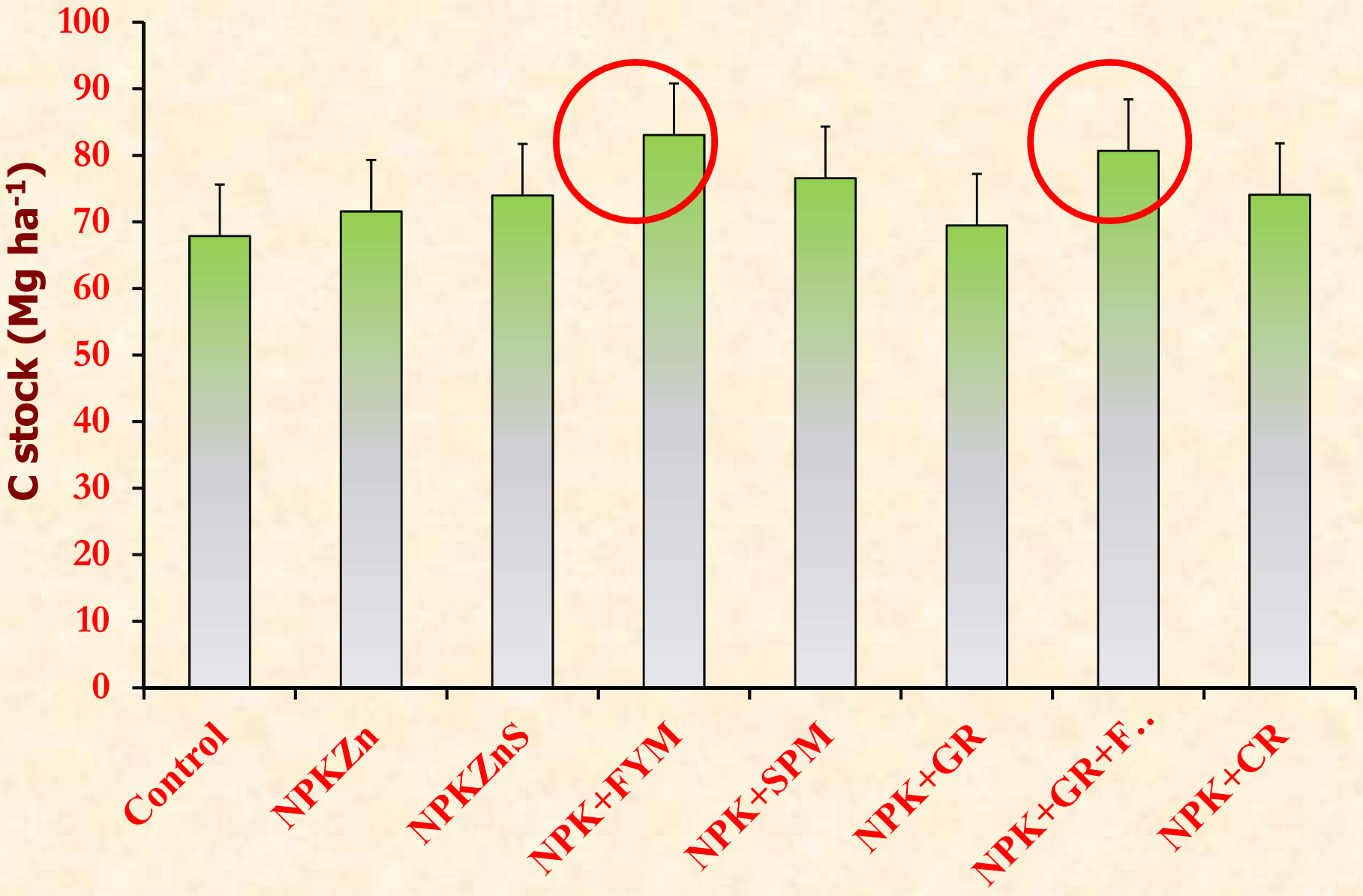
Karlen et al., 1994

Total organic C (TOC) under different nutrient supply options in rice-wheat system

Treatment	TOC (%) at different soil depths				
	(0-7.5 cm)	(7.5-15 cm)	(15-30 cm)	(30-45 cm)	(45-60 cm)
Control	1.15	0.96	0.67	0.59	0.27
NPKZn	1.22	1.10	0.74	0.64	0.28
NPKZnS	1.24	1.13	0.80	0.70	0.30
NPK+FYM	1.42	1.30	0.88	0.96	0.38
NPK+SPM	1.35	1.24	0.81	0.70	0.30
NPK+GR	1.30	1.23	0.75	0.70	0.28
NPK+GR+FYM	1.52	1.34	0.92	0.83	0.40
NPK+CR	1.60	1.32	0.79	0.65	0.31
LSD (p=0.05)	0.17	0.14	0.11	0.09	0.04

25% N substituted by organic sources

Effect of long-term fertilization and manuring on soil organic C stock (0-60 cm) in rice-wheat system

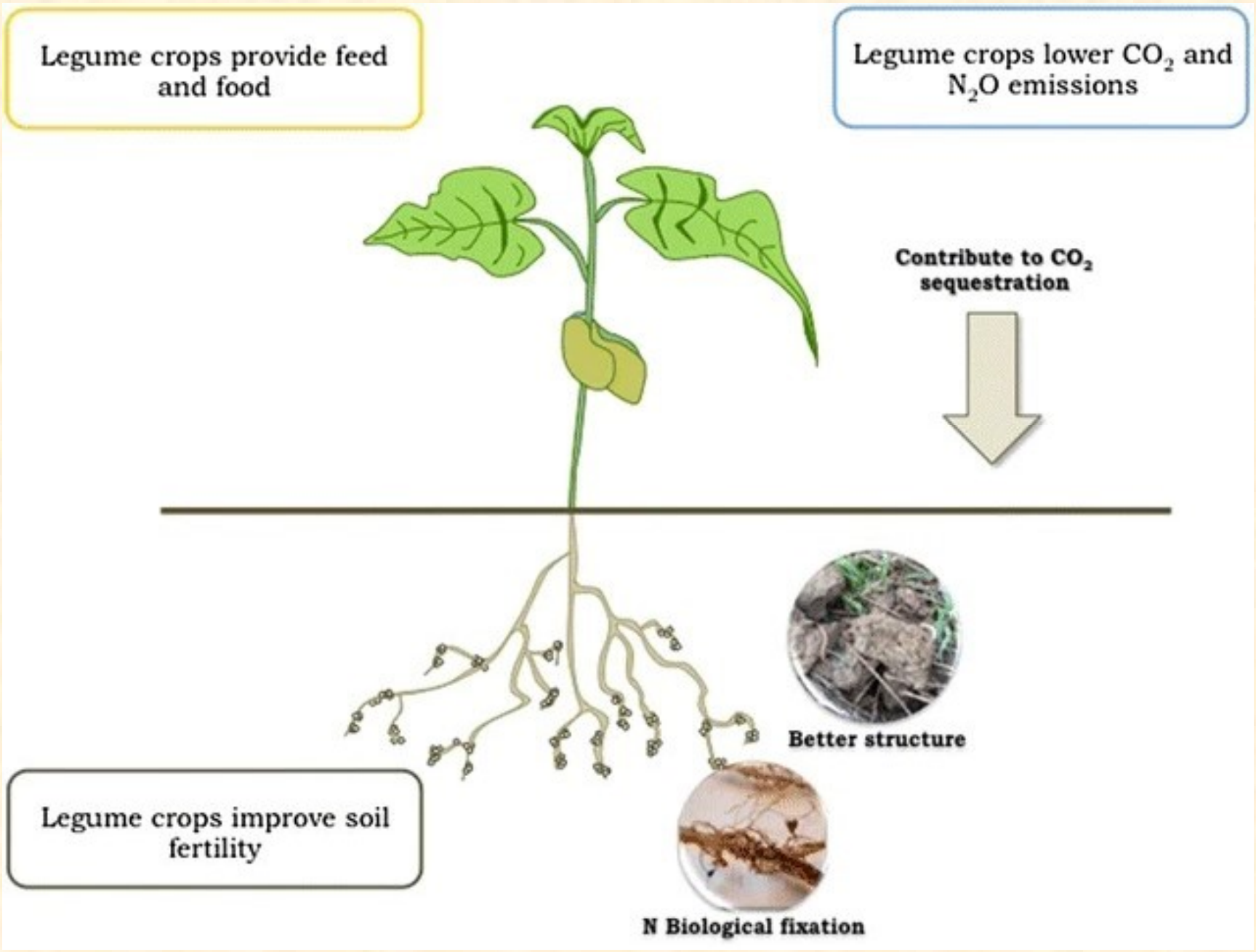


Bars indicate LSD at P= 0.05

Microbial inoculants in different forms and functions

Biofertilizer	Recommended for	Anticipated benefits
Rhizobium	**Pulses**: Chickpea, pea, lentil, black gram, green gram cowpea, pigeon pea **Oilseeds**: Soybean, groundnut	19-22 kg N
	Fodder: Berseem,	50-80 kg N
Azotobacter	Cereals, millets, cotton, mustard, vegetables, flowers	15-20 kg N
Azospirillum	Millets, sugarcane, cereals and co-inoculant for legumes	20 kg N
BGA	Rice	25-30 kg N
PSB	All crops	25 kg P_2O_5
VAM	For all agricultural and horticultural crops forest and plantation crops	Availability of P, Zn, Fe etc.

Inclusion of legumes in Cropping Systems

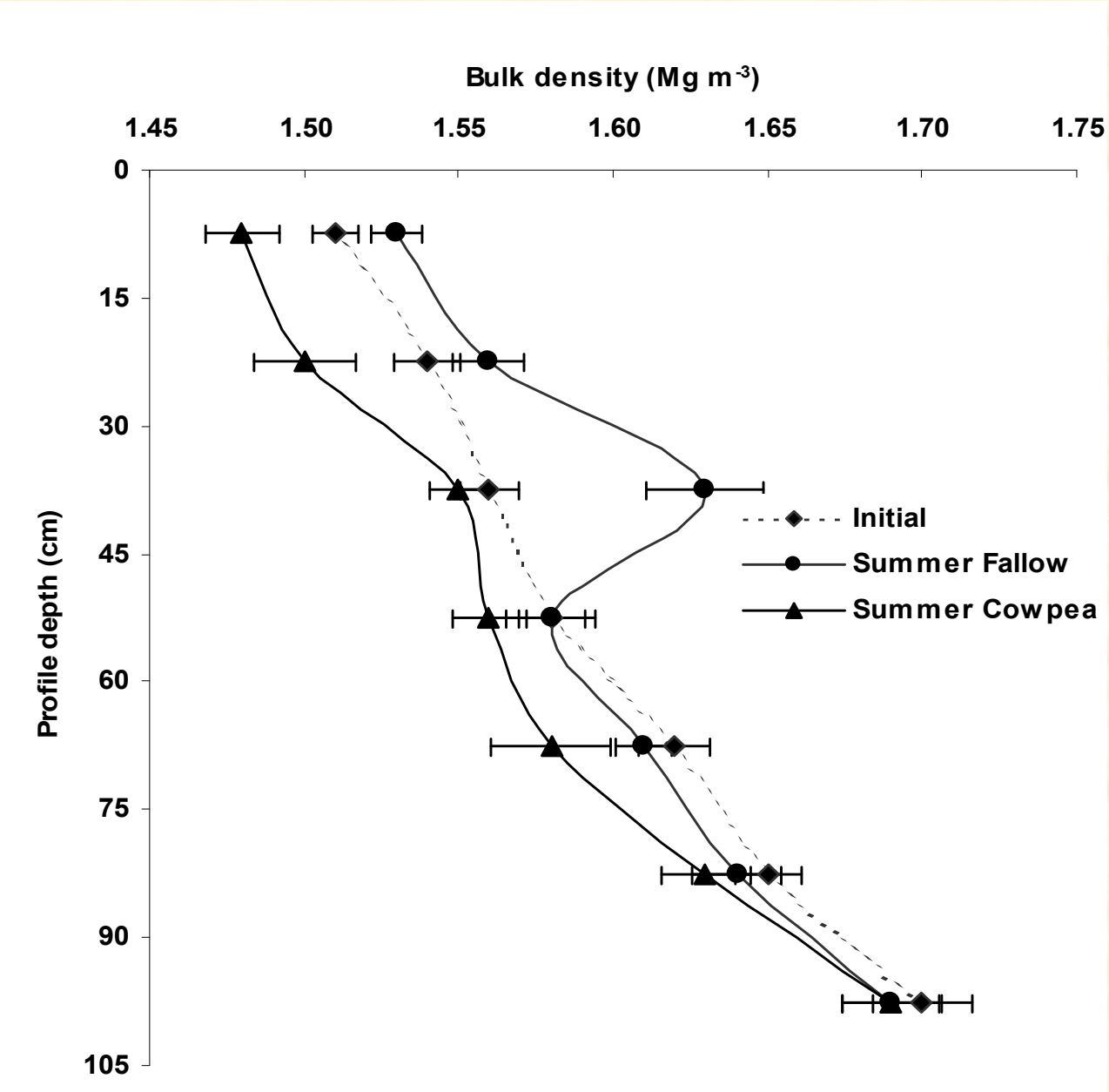


Green gram residue incorporation

Treatment	Grain yield (t/ha)		
	Rice	Wheat	Total
Faizabad (03 yrs)			
Green manure	5.14	4.91	10.05
Green gram residue	5.15	4.79	9.94
Palampur (02 yrs)			
Green manure	4.82	2.76	7.58
Green gram residue	5.00	3.07	8.67
Kharagpur (02 yrs)			
Green manure	3.65	2.96	6.62
Green gram residue	3.86	2.94	6.81

Source: AICRP-CS

Change in soil BD due to legume inclusion



Dwivedi et al. (2003)

Soil organic C and available N after wheat harvest

N rates	Organic carbon (%)		Available N (mg/kg)	
	After 02 crop cycles	% Change	After 02 crop cycles	% Change
Rice-wheat system				
N_0	0.24	(-) 4	55	0
N_{60}	0.27	(+) 8	58	(+) 5
N_{120}	0.30	(+) 20	62	(+) 13
N_{180}	0.31	(+) 24	65	(+) 18
Cowpea-wheat system				
N_0	0.32	(+) 28	61	(+) 11
N_{60}	0.34	(+) 36	65	(+) 18
N_{120}	0.36	(+) 44	67	(+) 22
N_{180}	0.37	(+) 48	67	(+) 23

Source: Yadav et al. (2004)

INDUCED DEFOLIATION IN PIGEONPEA : A Novel Technology to Improve Soil Health and Crop Productivity

Crop appearance before urea spray

Complete defoliation

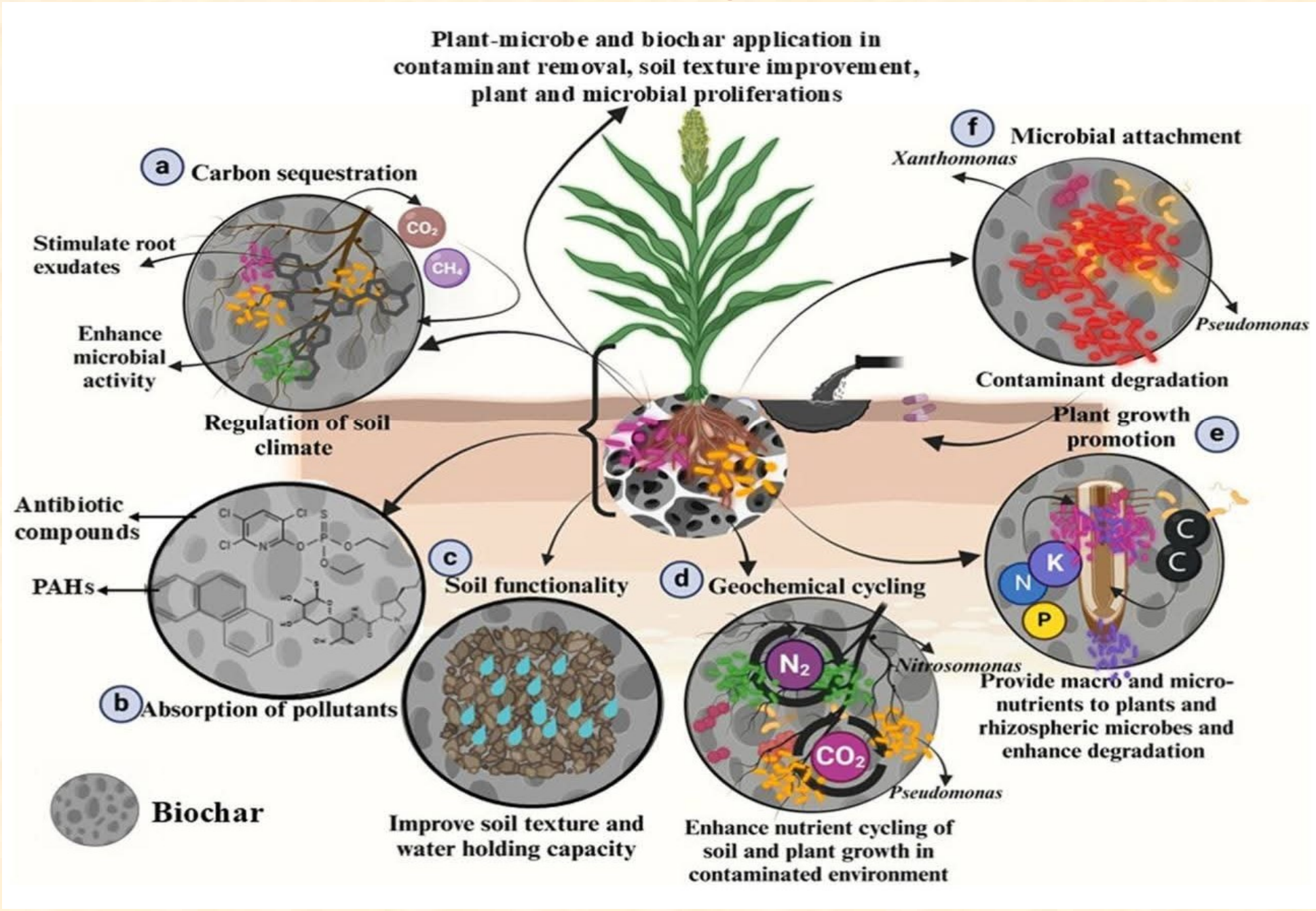
- Induced defoliation (ID) in extra-short duration pigeonpea was imposed through foliar spray of 10% (w/v) urea solution at physiological maturity, which resulted in almost complete defoliation within a week.
- ID contributed 1.0 to 1.2 t ha^{-1} of leaf litter to the soil.
- The additional leaf-litter recycled into the soil due to ID added about 50 kg N ha^{-1} besides substantial amounts of P, K and S.
- ID brought significant yield increase in subsequent wheat in pigeonpea-wheat cropping system.

P & K Enriched Compost

(using low grade rock phosphate and waste mica)

- Contains 1.4-1.5% N, 5.0–6.0% P_2O_5 and 2.5-3.0% K_2O.
- Addition of one tonne of enriched compost will supply 14-15 kg of N, 50-60 kg of P_2O_5 and 25-30 kg of K_2O.

Use of Biochar in Agriculture



Multi-enterprise farming system (Integrated Farming systems)

Crop component 1.8 ha

Fodder production – 0.4 ha
Grain production– 0.8 ha
Floriculture production–0.2 ha
Horticulture based–0.2 ha
Vegetable production– 0.2 ha
Sub total

Subsidiary component 0.2 ha

Milk + Compost + Biogas
Fruits & vegetables on pond dykes
Fish
Poultry & Ducks
Mushroom
Bee-keeping

CSSRI, Karnal

Conclusions

- ✓ Promote use of balanced fertilization (SSNM, soil test-based)
- ✓ Promote use of organic inputs with fertilizers (INM)
- ✓ Encourage farmers for green manuring
- ✓ Exploiting non-conventional resources (SPM, ID etc.)
- ✓ Inclusion of legumes
- ✓ Sustained release fertilizer materials
- ✓ Conservation agriculture


HEALTHY SOIL
IS AT THE HEART
OF OUR
CLIMATE SOLUTIONS
CENTER FOR
FOOD SAFETY
CARBON-RICH SOIL COURTESY OF SINGING FROGS FARMS

Thank you