Learnings from Long-term Experiments: Towards Regenerative Agriculture

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Regenerative Agriculture (RA)

- A system of farming principles and practices that increases biodiversity, enriches soils, improves watersheds, and enhances ecosystem services (Terra Genesis International, 2020).

- RA requires national-level planning but a high degree of local and regional self-reliance to close nutrient-flow loops (Dick Harwood, 1983).
- The main aim of RA is to improve the soil health or to restore degraded soil, which symbiotically enhances the quality of water, vegetation and land-productivity.

- Principles of RA include: minimum tillage, maintaining soil cover, improving C sequestration, encouraging water percolation, relying more on biological nutrient cycles, crop diversification, integration of livestock-------(Giller et al. 2021).

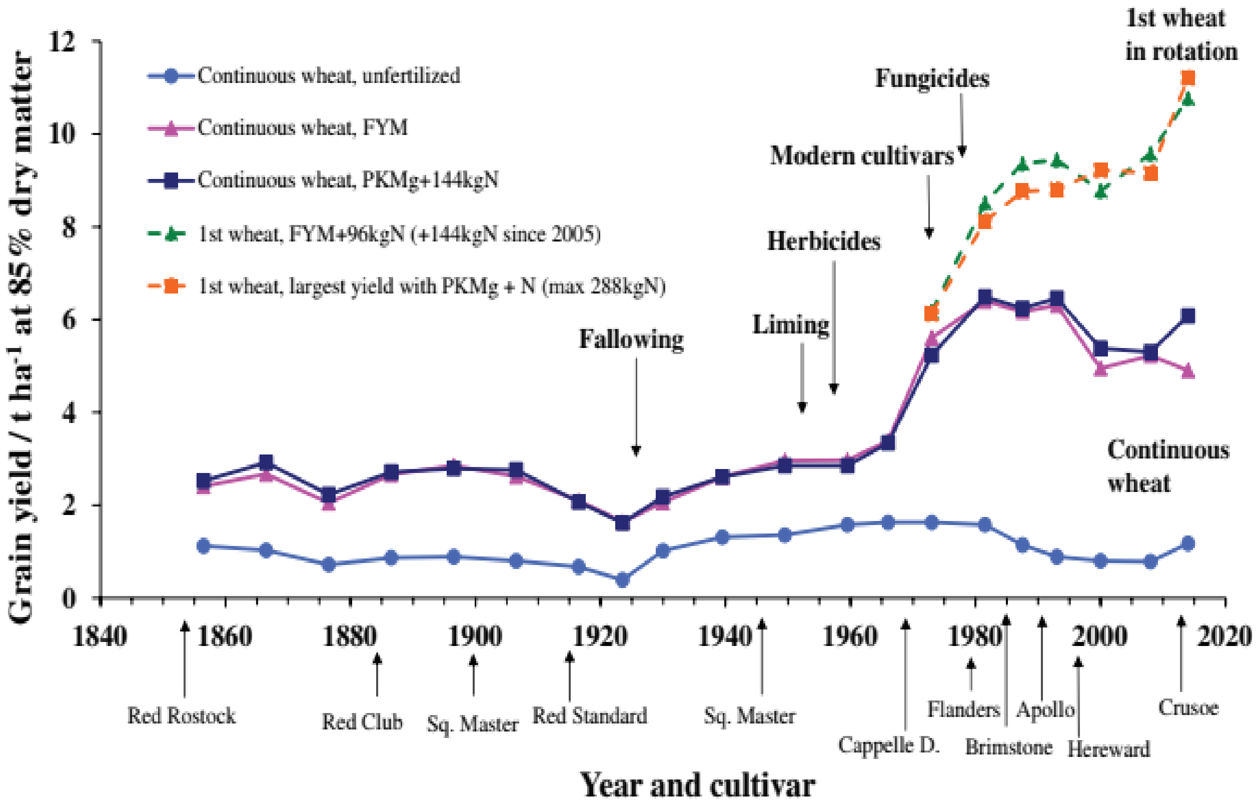
- RA is practiced on ~180 Mha globally (Al-Kaisi and Lal, 2021).

- Economic benefits are most evident in smallholder farms.

LTEs – Global scenario

- >600 active LTEs with more than 20 years of age across the globe.
- Europe has more than half of the global LTEs.
- LTEs cover many soil types and diversified cropping systems including cereals, millets, sugar crops and legumes.
- Generally set-up to study the effect of crop rotations, monocultures, organic and mineral fertilization, application of micronutrients, and response of new crop varieties.

The Rothamsted long-term experiments



Mean long-term yields of winter wheat (1852–2016) showing selected treatments, important changes in management and cultivars grown.

- Originally designed to study the N, P, K, Na, Mg, and Si needs of the field crops then grown in England (Lawes and Gilbert, 1843).
- Soil acidity developed in 1940s due to continuous application of Ammonium Sulphate, affecting crop yields drastically.
- Liming was introduced in 1951 to correct soil acidity.
- More changes were introduced in 1970s and thereafter in management, cropping, type of fertilizers, and crop varieties to ensure that the experiments remain relevant to farming practices.

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The Rothamsted long-term experiments

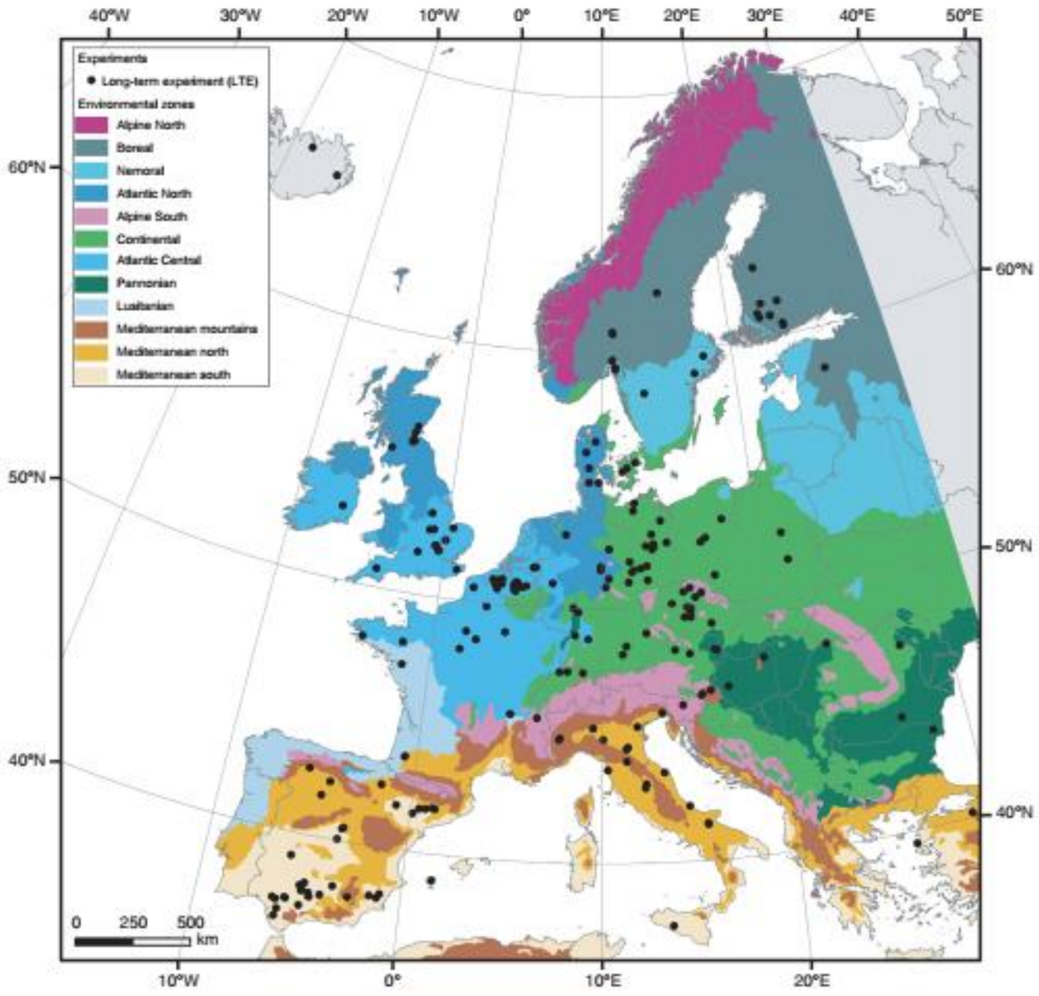
Limitations to achieving the "4 per 1000" carbon goal in practical agriculture over large areas:

- Farmers don't have necessary resources (e.g. insufficient manure).
- Some practices favouring improvement in SOC already widely adopted.
- Practices uneconomic for farmers- potentially overcome by changes in regulations or subsidies
- Practices undesirable for global food security

It is more realistic to promote practices for increasing SOC based on improving soil quality, as small increases can have large benefits, though not necessarily translating into increased crop yield.

Poultan et al. (2018)

Learnings from European LTEs



- Productivity was hampered by non-inversion tillage.
- SOC contents were increased significantly following organic fertilizers and non-inversion tillage.
- GHG emissions were increased by slurry application and incorporation of crop residues.
- Alternative management practices beneficial to one group of indicators (e.g. organic fertilizers for biological soil quality indicators) are not necessarily beneficial to other indicators (e.g. increase of crop yields).

Sanden et al. (2018)

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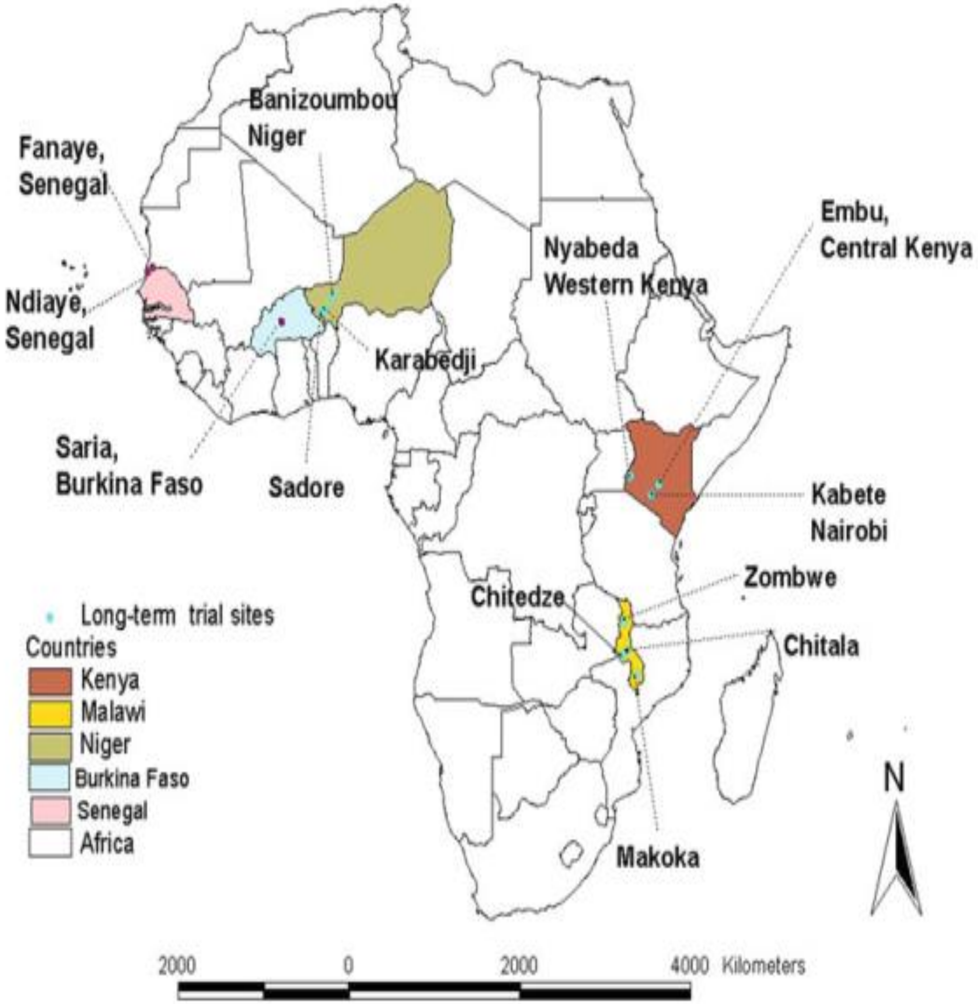
Learnings from African LTEs



- Use of fertilizer alone led to decline in SOC and yield.
- Prolonged treatments using only inputs of organic matter showed yield decline.
- Crop rotation with legumes and fallow periods sustained crop yields vis-à-vis monoculture.
- Conjoint use of fertilizers and organic inputs improved yields and SOM, and maintained desired soil nutrient balance.

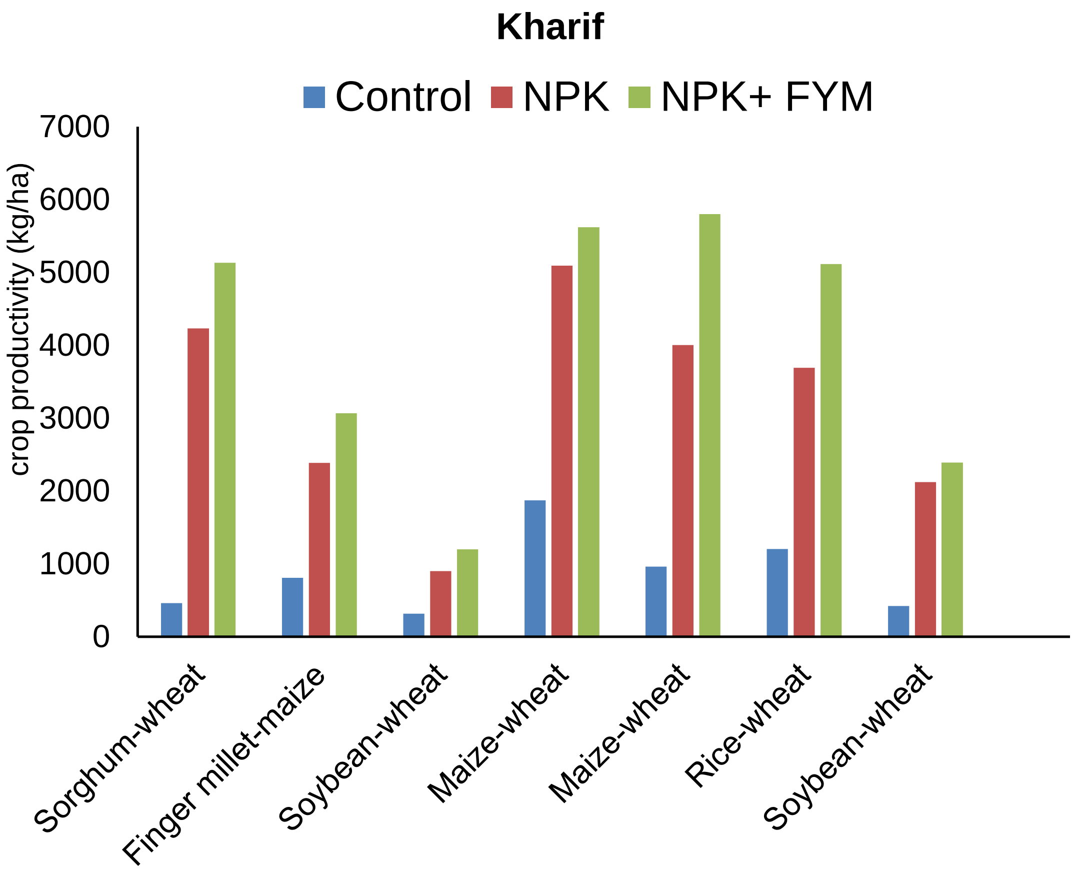
Bationo et al. (2012)

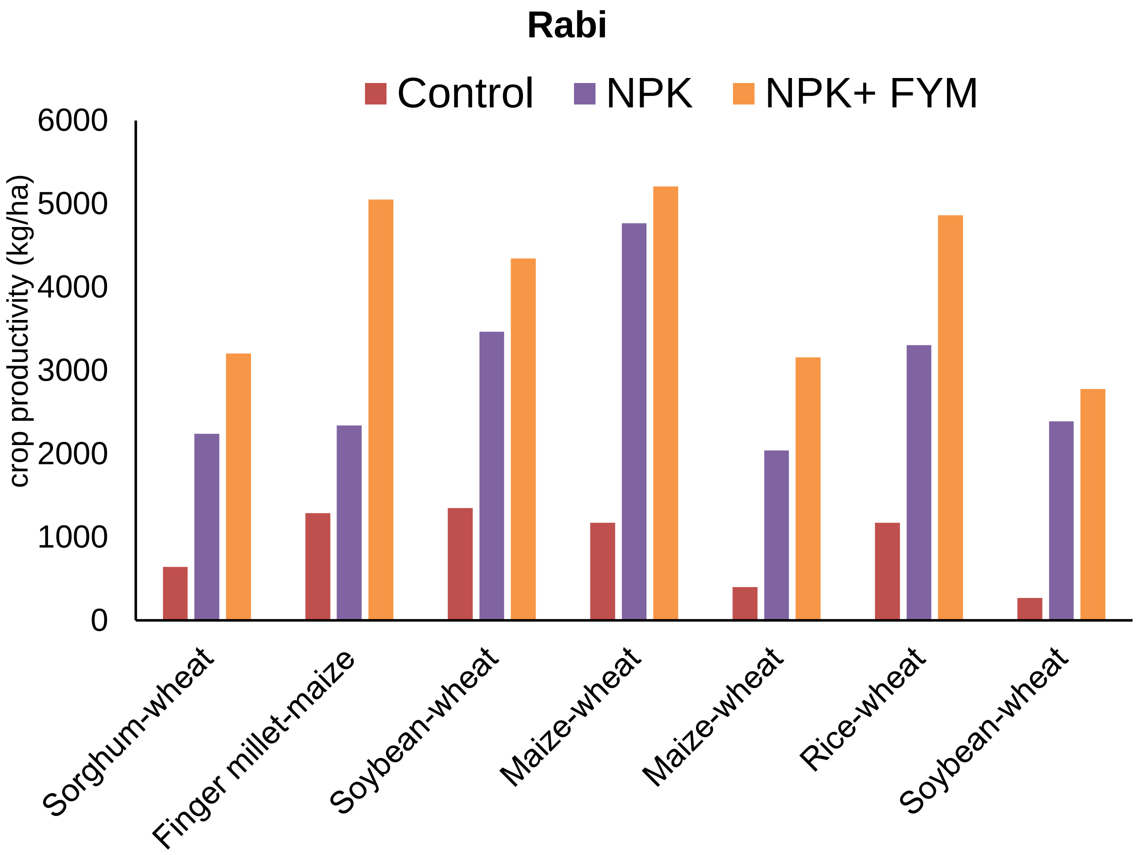
Learnings from Indian LTEs

- Fertilizers applied at recommended rates generally maintained or improved SOC levels, except the locations initially rich in SOC.
- SOC contents and stocks were highest under integrated plant nutrient supply (IPNS) through fertilizers and organics irrespective of soil types or cropping systems.
- It was not possible to sustain high productivity levels with fertilizers alone, whereas IPNS proved advantageous.
- IPNS improved soil physical and biological properties over sole fertilizer application.
- Unbalanced and inadequate fertilizer input resulted in low crop yields and depletion in soil health at most locations.
- Crop response to P, K, S and Zn increased over time under intensive cropping, thus underlining the need to revise fertilizer recommendations.
- In general, annual K balances were negative in all cropping systems, suggesting mining of K from soil.
- Continued neglect of K input tended to modify soil mineralogical make-up, indicating deterioration in K supplying capacity of soils.

https://aicrp.icar.gov.in/ltfe
Singh and Wanjari (2017); Singh et al. (2018)

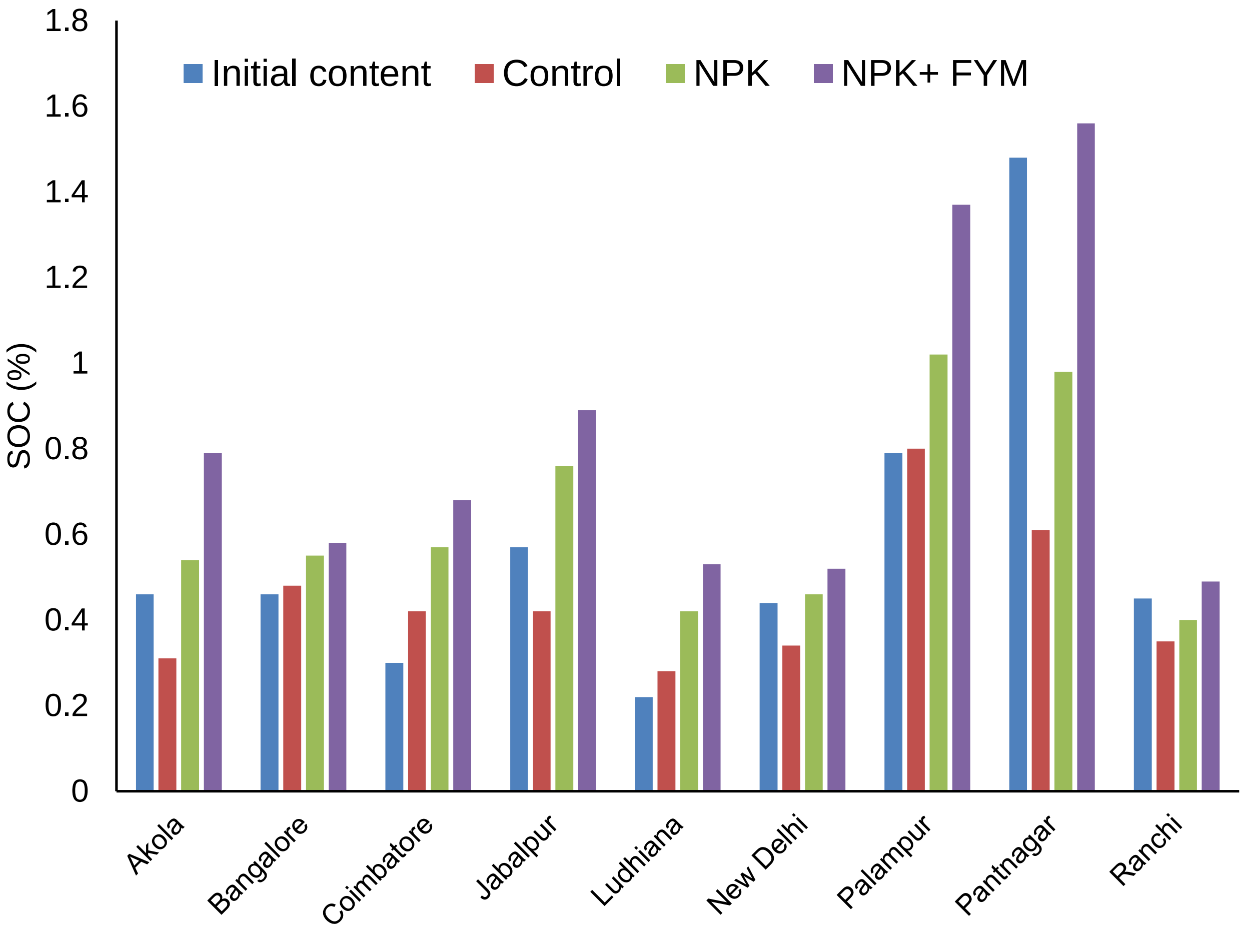
Crop productivity as affected by long-term (45+ yrs) nutrient supply options





- **Inclusion of organic manure in fertilizer schedule helped maintaining high yields under intensive cropping systems.**
- **Yield response to different nutrients increased with the passage of time, necessitating revision in fertilizer prescriptions.**

Changes in SOC under long-term cropping and manuring



AICRP-LTFE Reports

Locations (Initial SOC stock, Mg ha^{-1}	Treatments	Steady state SOC stock (Mg ha^{-1})	Years to reach steady state
Jabalpur (33.8)	Nil	29.0	55
	NPK	41.0	48
	NPK+FYM	60.0	108
Palampur (40.5)	Nil	40.6	1
	NPK	49.0	40
	NPK+FYM	57.0	62
Ludhiana (14.7)	Nil	15.9	44
	NPK	26.3	95
	NPK+FYM	37.6	116

Jha et al (2021)

- **Balanced fertilization increases SOC content, the levels are highest under IPNS.**
- **IPNS and balanced fertilization will lead to carbon stabilisation at higher levels.**

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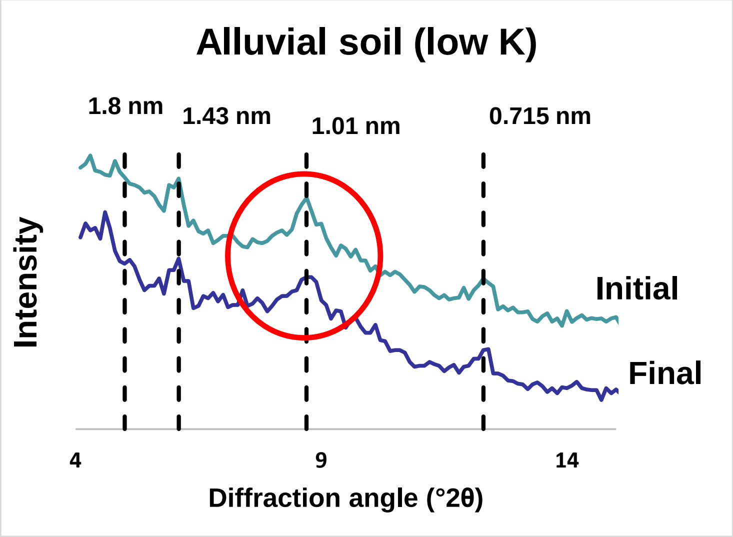
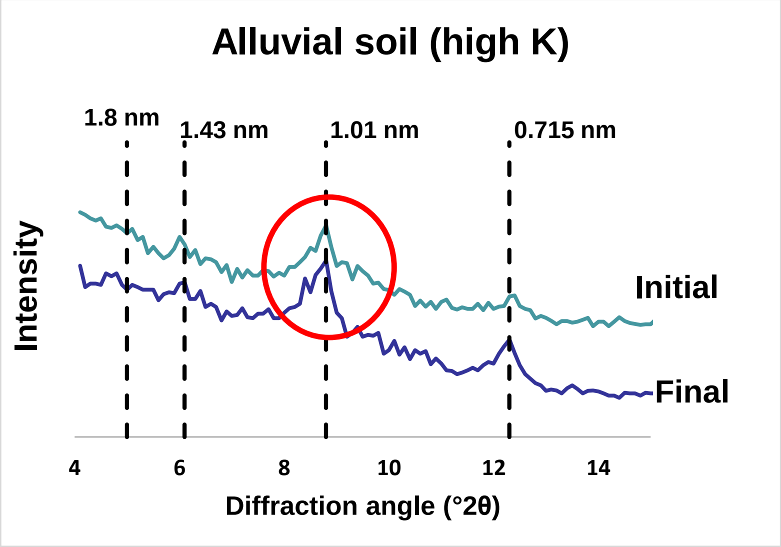
Excessive K mining distorts soil mineralogical make-up

Approximate quantities (%) of different minerals in clay fraction of alluvial soil

Mineral	Treatments						Uncultivated
	Control	100% N	100% NP	100% NPK	150% NPK	100% NPK+FYM	
Mica	48	46	42	51	53	50	54
Vermiculite	7	5	7	5	5	5	6
Smectite	23	18	12	10	17	18	11
Kaolinite	22	31	39	34	25	27	29





- **Continued omission of K led to depletion of mica in clay fraction of different soils, implying decrease in K supplying capacity.**
- **LTEs suggested possible conversion of illite to illite/vermiculite interstratified minerals.**
- **Clay size mica tended to loose crystallinity & become finer continued puddled rice cultivation.**

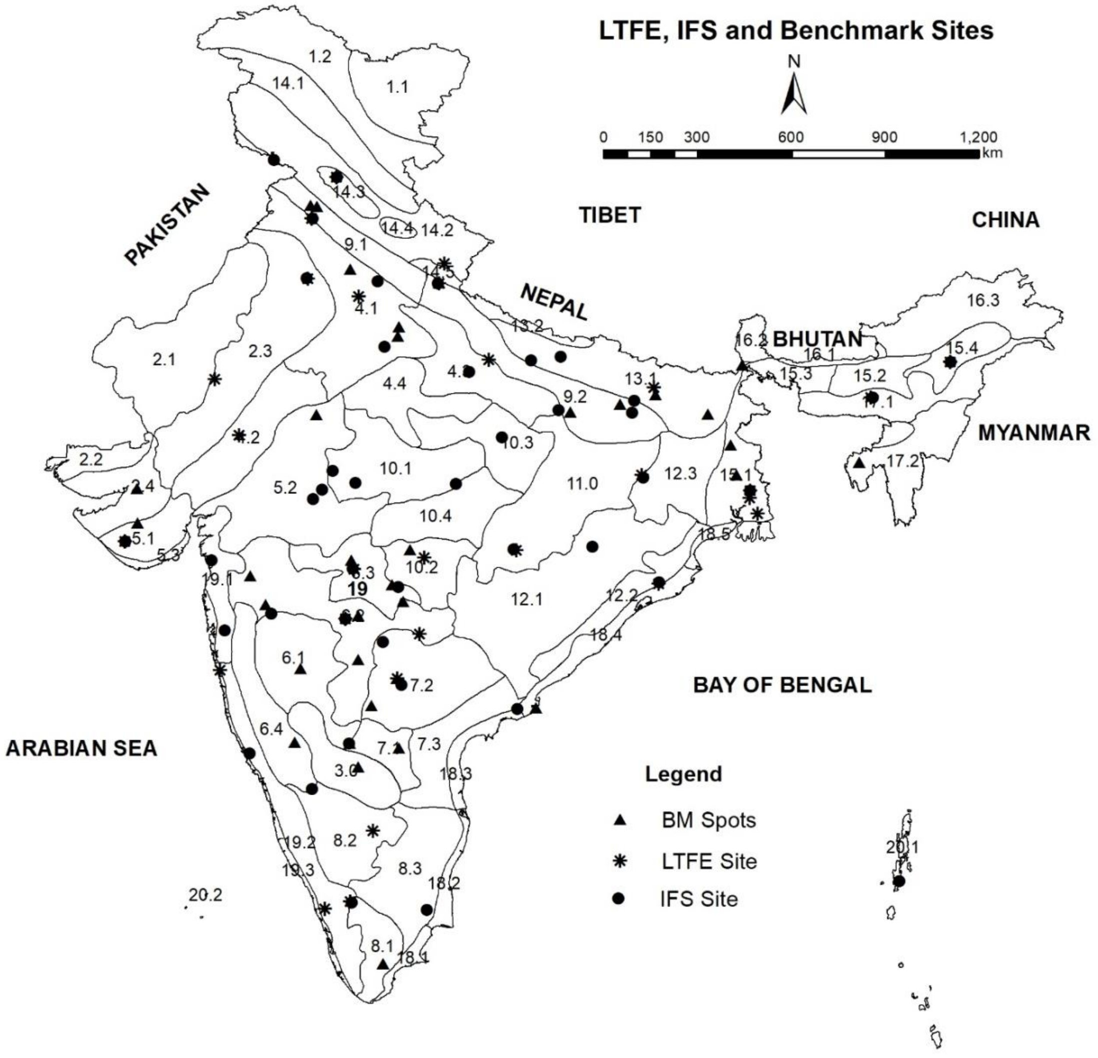
Das et al. (2018), Chatterjee et al. (2021)

Accommodating the tenets of RA in on-going LTEs

- Existing LTEs (AICRP-LTFE, DA, IFS) need to be modified to retain their relevance, and converge with present-day farming issues.
- Less-relevant treatments have to be replaced with the desired ones involving organic inputs, tillage, residue recycling and crop diversification.
- Possibilities to be explored for need-based bifurcation of plots and expansion of the layout to adjoining uncultivated area.
- Measurement of soil physical and biological parameters to get as much attention as soil fertility parameters.

An Expert Committee could be constituted to suggest such modifications as well as any new experiments under the broad framework of RA.

Benchmark sites for soil health assessment



- Permanent sites under AICRP-LTFE, AICRP-IFS, and those earmarked by NBSS&LUP to be used as benchmark sites.
- **Minimum dataset**: Soil pH, total carbon (SOC and SIC), available nutrients, earthworm population, soil respiration, aggregate stability, hydraulic conductivity.
- **Soil parameters** to be measured in **surface and sub-surface layers**.
- Proper record of annual productivity, weather parameters, agronomic management practices…
- "**BHOOMI**" Geoportal to be used as data repository and dissemination platform.

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Path Ahead to strengthen soil health management towards RA

- Greater emphasis on organics other than FYM e.g., enriched composts, crop diversification with legumes, CR and waste recycling, industrial by-products…
- Develop/refine nutrient management protocols for RA and IFS based on nutrient fluxes and flows
- Establish mechanized composting units in rural areas to promote availability of quality manure; Formulate cropping system-specific fertilizer prescriptions involving locally available organic sources.
- Incentivize fertilizer best practices; think of incentivizing 'nutrient smart villages'
- Soil health rejuvenation campaigns involving field demonstrations on RA technologies and informal education/skill development to enhance farmers' awareness on bio-waste recycling
- Converge RA with Govt initiatives e.g., NMSA, DFI, NFSM, PKVY, SHC, MIDH…

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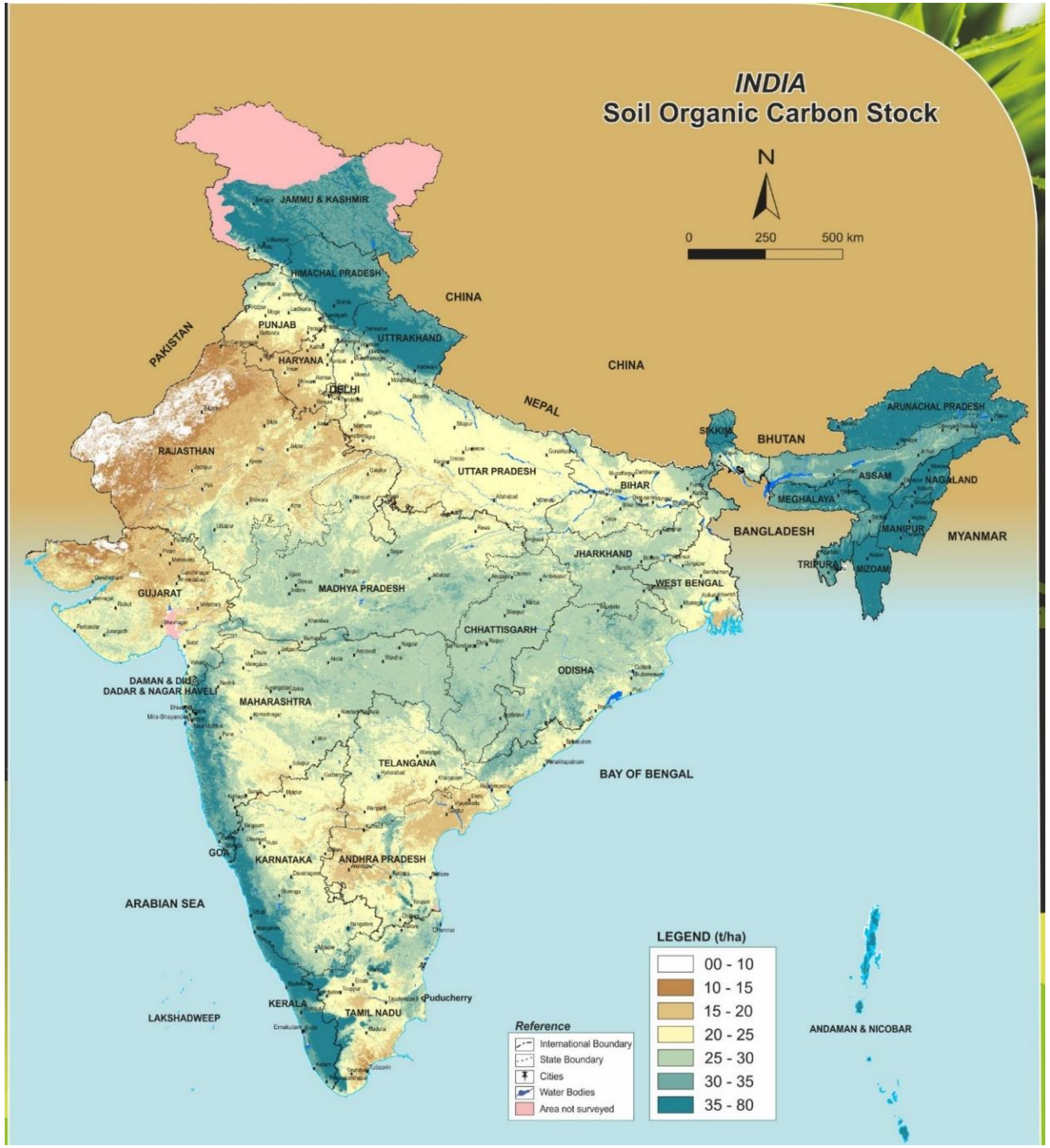
Soil organic carbon stock in Indian soils (2018)



ICAR-NBSS&LUP, in collaboration with ICAR-IISS, developed SOC stock (0-30 cm) map of India:

Northern Hills, NEH & Western Ghats: 30-70 t/ha

Central and eastern India: 25-35 t/ha

Southern peninsula and IGP: 15-25 t/ha

Western arid regions: <15 t/ha

Changes in SOC stocks need to be measured periodically at local, regional and national level to achieve the objectives of RA.

There is need to establish a dedicated Centre for Soil Carbon Research.

Epilogue

- RA is an umbrella term which encompasses the principles and practices that restore/ improve soil health and ensure sustained high productivity while minimizing environmental footprint.
- Only evidence-based benefits of RA need to be recognized, to avoid its misconstrued conformity with the variants of natural farming.

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