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Impact of Long-term Fertilization and Manuring on Carbon Carrying Capacities of Alfisols

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September 25-28, 2024
Nanjing, China

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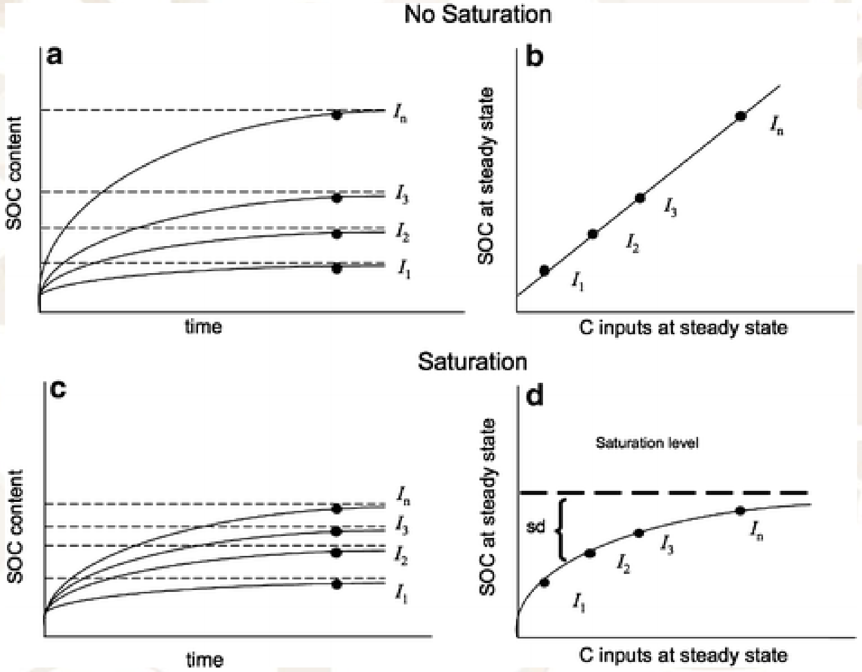
Introduction

- Soil organic carbon (SOC) is a key soil property considered as backbone of soil quality and plays a crucial role in greenhouse gas balance and food production
- SOC is important for restoring soil quality, creating climate-smart agro-ecosystems, and enhancing input use efficiency.
- The depth of the soil, clay content, mineralogy, nutrient reserve and initial SOC stock are some of the key factors that determine the SOC sequestration capacity. The maximum attainable SOC level in soil is critical in determining the C sequestration potential (CSP) of a soil.
- There is an upper limit to SOC storage and soil C saturation level.
- Soil C saturation is the level of maximum amount of C that can be sequestered physically and chemically, and this level is likely to be greater than the current level of sequestration. The soil C saturation deficit (Sd) will decrease as the soil approaches C saturation.

- Therefore, before designing the C input rate, it is essential to know the degree of C saturation level of a specific soil.
- The carbon saturation level of soils varies based on different soil types, carbon input, texture, clay mineralogy, and climate.
- Long-term fertilizer experiments (LTFE) are being conducted across various agro-climatic regions in India with different soil types, making them an ideal location for evaluating C Sd.

- Enrichment and stabilization of C is also greatly influenced by the chemistry of C inputs and soil microbial community structure that trigger C cycling and humification process in different soil types.
- Information on C-carrying capacities of major soil orders located in various agro-climatic regions would help in designing efficient nutrient and manure management strategies for long-term C sequestration, which is presently lacking in India and many other countries.
- India lacks studies on the C Sd of Alfisols in various agro-climatic regions where major agricultural crops are grown, and these soils have distinct textures and mineralogical properties.



(Stewart et al., 2007)

- This study explores how soil texture, clay mineralogy, crop management, and climate influence SOC carrying capacity.
- The Sd of soil C estimated from the soil's maximum C carrying capacity and present level of C as envisaged from the current study would help assess CSP in agro-ecological region basis.
- We hypothesize that certain nutrient management treatments, such as 100% NPK, 100% NPK+Lime, and 100% NPK+FYM, may have reached or approached C saturation levels in the Alfisols studied across different agro-climatic regions

Methodology

- *Study area*: LTFE sites (Pattambi, Kerala and Bhubaneswar, Odisha) in India since 1996
- *Major cropping system*: Rice - Rice
- *The treatments* : Control, 50% NPK, 100%NPK, 150% NPK, 100%NPK+ FYM and 100%NPK + Lime
- *The soil samples*: 0-15 and 15-30 cm depths.
- *Soil Texture*: Pattambi (Sandy clay loam), Bhubaneswar (Sandy loam)
- The mean annual estimated return of carbon (MAERC) input: based on observed and derived values of C content in root, rhizodeposition, stubble biomass and leaf fall of the crop in the cropping systems.

- *The Carbon saturation model* (Stewart et al.,2007):

  dCt/dt = I (1- Ct/Cm) – kCt (to estimate C Sd and maximum C carrying capacity (Cm) where Ct is SOC content)

- *The Sd is defined as*: Sd= 1- Ct/Cm.

- Decay constant, *(k):* dCs/dt versus MAERC inputs data and

- Equating the relationship with dCs/dt=*h*A – *k*Cs (y = mx+C) (Jenkinson, 1988),

  where slope represents the humification rate constant, *h* of the straight line curve

  and intercept represents *k*Cs.

- The value of *k* was substituted in the above equation and Cm and Sd were estimated

  where Cs is the initial SOC, and A is the MAERC input data during the period of study.

- The amount of C input required to maintain the SOC at equilibrium (A_E) was estimated by making dCs/dt equal to 0 and A=*k*Cs/*h*.

Results

Mean annual estimated return of C (MAERC) to the Alfisols under rice-rice cropping system

Fertilization	MAERC (Mg ha^{-1} yr^{-1})	
	Rice-Rice (Pattambi)	Rice-Rice (Bhubaneswar)
50% NPK	2.61d§	1.62e
100% NPK	2.85c	1.71d
150% NPK	2.96c	1.92b
100% NPK + FYM	6.10a	5.45a
100% NPK + Lime	3.40b	1.79c
Control	1.87e	0.90f

The MAERC across the soil types followed the order 100%NPK + FYM> 150%NPK = 100%NPK +Lime > 100%NPK > 50%NPK > control.

The MAERC of Pattambi soils was 1.65 times higher than Bhubaneswar.

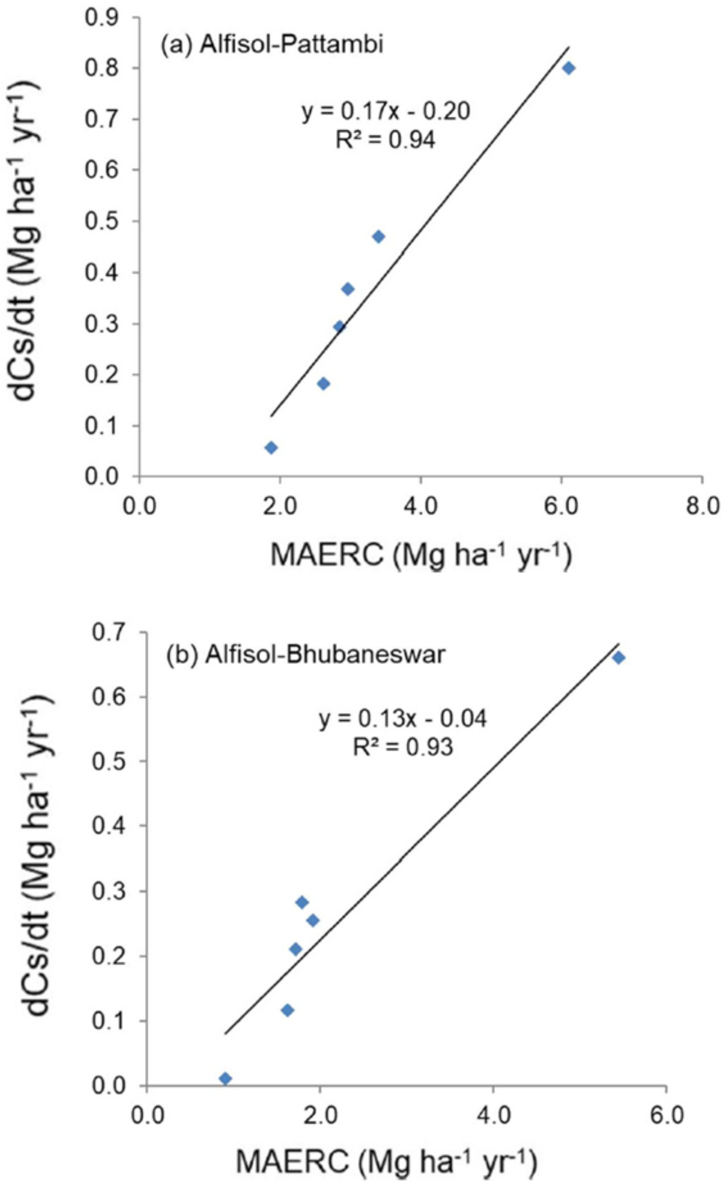
Soil organic C (SOC) stock, SOC sequestration and SOC stabilization in the two Alfisols

Fertilization	**SOC stock ($Mg\ ha^{-1}$)**		**Mean**	**SOC sequestration ($Mg\ ha^{-1}$)**		**Mean**	**SOC stabilization (%)**		**Mean**
	Alfisol-PTMB	Alfisol-BHNS		Alfisol-PTMB	Alfisol-BHNS		Alfisol-PTMB	Alfisol-BHNS	
50% NPK	28.1e§	14.2j	21.2E	3.35ef	2.10f	2.73E	4.98e	7.41d	6.20D
100% NPK	30.1d	15.9ij	23.0D	5.35d	3.80ef	4.58D	8.42d	12.3bc	10.4C
150% NPK	31.4c	16.7hi	24.1C	6.65c	4.60de	5.63C	10.8cd	13.5b	12.2B
100% NPK+FYM	**39.2a**	**24.0g**	**31.6A**	**14.5a**	**11.9b**	**13.2A**	**12.3bc**	12.1bc	12.2B
100% NPK+Lime	33.2b	17.2h	25.2B	8.45b	5.10d	678B	12.1bc	**15.6a**	**14.0A**
Control	25.8f	12.3k	19.1F	1.05f	0.20g	0.63F	0.21f	1.11f	0.70E
Mean	**31.3A**	**16.7B**		**6.55A**	**4.62B**		**9.77B**	**12.2A**	

An integrated application of 100%NPK with either lime or FYM is recommended to maintain the sequestration and stabilization of SOC in the studied soils.

Humification rate constant (h), decay rate constant (k), annual C inputs to maintain SOC at equilibrium (A_E) and maximum C carrying capacity (C_m)

Soil	h (yr^{-1})	k (yr^{-1})	A_E ($Mg\ ha^{-1}\ yr^{-1}$)	C_m ($Mg\ ha^{-1}$)
Alfisol-PTMB	0.17	0.01	1.84	39.3
Alfisol-BHNS	0.13	0.003	0.39	21.7



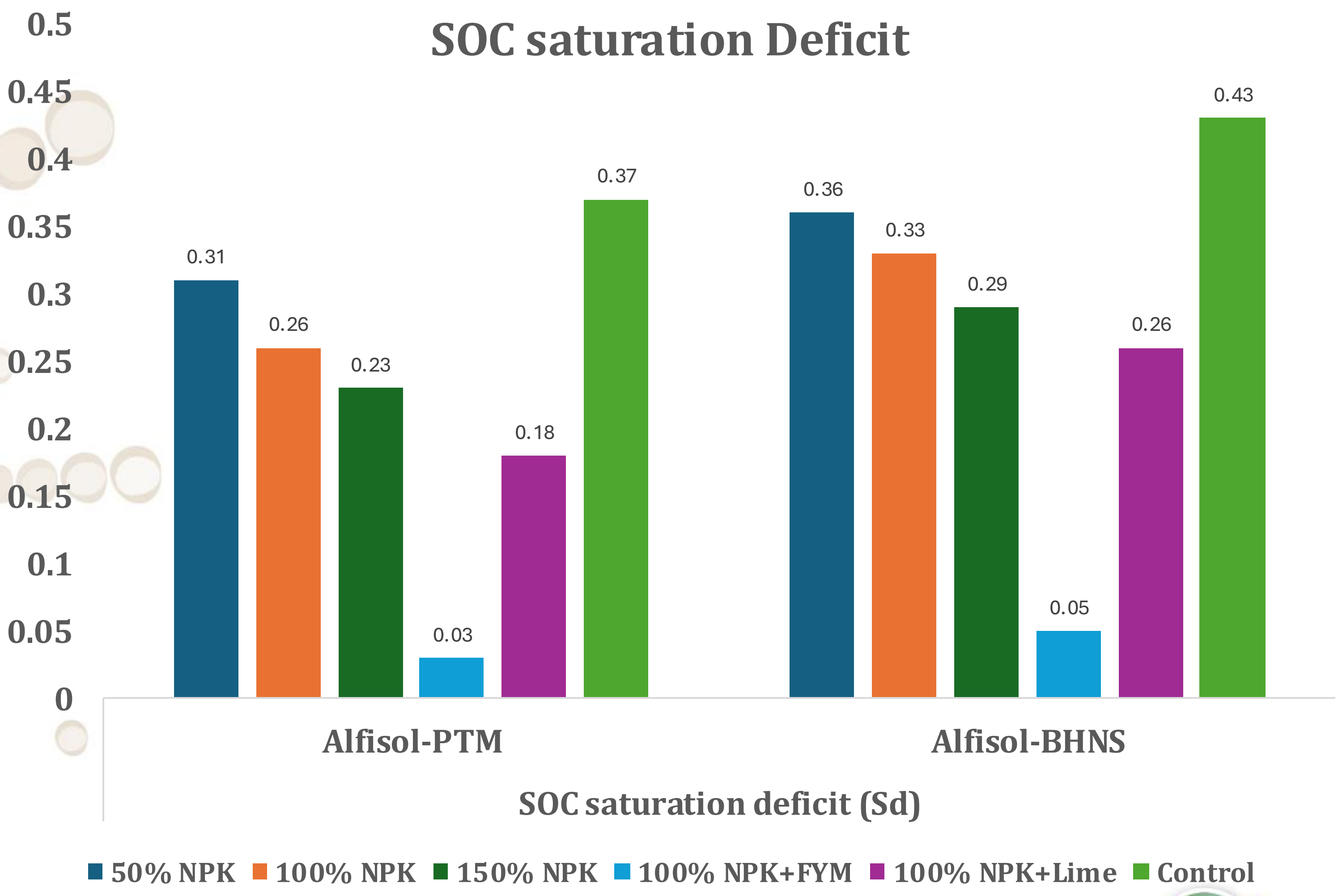
Saturation Deficit

- The Sd value was the highest in the control treatment and lowest in 100% NPK + FYM treatment, signifying a higher CSP of the former soil than the later.

- Therefore, 100%NPK +FYM treatment would require a minimum threshold level of C addition to maintain the SOC at equilibrium.

- Alfisol-PTMB showed lower Sd than BHNS , which implies that long term fertilization helped PTMB to approach more towards Cm than BHNS.

- The high SOC sequestered in PTMB compared to BHNS reflects the lower Sd in PTMB
- The study clearly demonstrated that proper management strategies are capable of reducing Sd.



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Conclusion

- Though clay mineralogy and texture are important factors for SOC stabilization other factors like, growing conditions (aerobic versus anaerobic), litter chemistry, climate are also equally important which should be considered while formulating management strategies for soil C sequestration.
- Soil texture, MAERC and climate largely influenced the C sequestration and Cm in the Alfisols under study.
- The integrated application of 100%NPK with either lime or FYM is recommended for higher stock, sequestration and stabilization of SOC.
- The C Sd narrowed down in the treatment 100%NPK+FYM due to its progress towards C saturation level of soil.
- Therefore, blanket recommendation of FYM needs to be modified depending upon the C saturation level of soil and assessing the minimum C input required to maintain SOC at equilibrium (A_E). Otherwise, the conventional practice of blanket recommendation might release a large amount of C in the form of CO_2.
- The higher *h* in Alfisol-PTMB than Alfisol-BHNS indicated a higher conversion of input C into stable C in Alfisol-PTMB by the humification process.
- The CSP of the soils could be further increased via innovative approaches such as increasing soil's reactive mineral contents to lock additional C.
- The soil thus reaching saturation needs lower C inputs than that is away from the C saturation point. Thus, the information on soil's C saturation level is essential to save precious carbonaceous materials and reduce emissions of CO_2.

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