

Effects of Fertility Management on Soil Carbon Stocks under Different Agro Climatic Zones of Andhra Pradesh

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Abstract Enrichment of soil organic carbon (SOC) stocks through sequestration of atmospheric CO₂ in agricultural soils is important because of its impacts on soil quality, agronomic production, and adaptation to and mitigation of climate change. Among the different Agro Climatic zones, Godavari Zone showed higher content of soil organic and inorganic carbon stock (38.07 and 7.17 Mg ha⁻¹, respectively) followed by Northern Telangana Zone (22.93 and 10.32 Mg ha⁻¹, respectively), Southern Telangana Zone (17.28 and 6.08) and Scarce Rainfall Zone (15.38 and 6.61). The results related to total carbon stock (Mg ha⁻¹) and carbon sequestration rate (mg ha⁻¹ yr⁻¹) revealed that Godavari Zone recorded higher total carbon stock (45.12) and carbon sequestration

rate (1.04) followed by Northern Telangana Zone (33.25 and 0.39) and Southern Telangana Zone (21.83 , 0.70) whereas lowest was recorded under Scarce Rainfall Zone (20.63, 0.08). The treatment receiving inorganic fertilizers along with organic manures resulted higher amounts of total carbon stock in all the zones. The percent increase of total carbon stock over control was nearly 200, 100, 47, 31 and 22% in GZ, STZ (maize-onion), SRZ, NTZ and STZ (rice-rice), respectively. Integration of inorganic fertilizer with organic sources such as FYM enhanced the soil organic carbon content by 17-100%. Further, addition of organic manures improved the macro aggregates and carbon storage inside the aggregates which was protected from decomposition.

Keywords Carbon stocks, Carbon sequestration rate, Integrated nutrient management.

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Introduction

The increase in greenhouse gases (GHG) in the atmosphere and the resulting climatic change will have major effects in the 21st century. Taking action on C sequestration under the Kyoto Protocol or any post-

Table 1. Long-term effects of INM treatments on organic carbon content (%) of the soils under different agro climatic zones.

Treatments	Southern Telangana Zone (Rajendranagar)		Northern Telangana Zone (Jagtial)	Godavari Zone (Maruteru)	Scarce Rainfall Zone (Ananthapur)
	Rice-Rice	Maize-Onion	Rice-Rice	Rice-Rice	Groundnut-fallow
Control	0.57	0.36	0.80	0.53	0.45
100% Inorganic	0.68 (19.3%)	0.58 (61.1%)	0.88 (105)	1.25 (135.8%)	0.58 (28.8%)
100% Organic	–	0.62 (72.2%)	1.01 (26.3%)	1.85 (249.1%)	0.67 (48.9%)
50% Inorganic + 50% Organic	0.72 (26.3%)	0.70 (94.4%)	–	1.88 (254.7%)	0.61 (35.6%)
100% Inorganic + FYM @ 5 t ha ⁻¹	–	–	–	1.58 (198.1%)	–
100% Inorganic + FYM @ 10 t ha ⁻¹	–	–	1.04 (30%)	–	–

Kyoto treaty will not only stimulate important changes in land management but will also, through the increase in organic matter content, have significant direct effects on soil properties and a positive impact on environmental or agricultural qualities and biodiversity. In order to estimate the potential of carbon sequestration in soils under various scenarios over the next 25 years [1], two aspects need to be distinguished. What are the original C stocks in soils; and what are the changes in C stocks. Organic matter that is above the soil surface in the litter layer is not taken into account in the assessment of soil carbon stocks. It is estimated that the land use change result in the transfer of 1–2 Pg of carbon per year from terrestrial ecosystem to the atmosphere of which 15–17% is contributed by the decomposition of SOC [2]. The global climate change as a result of green house gas emission such as CO₂ has brought a new emphasis and new perspective to the importance of SOM and SOC which not only improves soil properties but also shows its impacts on global carbon budget through sequestration of atmospheric carbon in soil [3], [4]. The total carbon pool constitutes a major global reservoir comprising of SOC pool and SIC pool. The global estimate of SOC pool and SIC pool was about 1550 and 950 Pg, respectively up to one meter depth [5]. The present attempt is made to review the work done in this particular aspect of estimates of carbon stocks (both SOC and SIC) in different Agro Climatic Zones of Andhra Pradesh under different cropping sequences.

Materials and Methods

The long-term fertilizer experiments are being con-

ducted in Andhra Pradesh and Telangana under four different agro climatic zones, viz., Southern Telangana zone [rice—rice (27 years) and maize-onion (13 years) cropping systems at All India Co-ordinated Research Project on Integrated Farming systems, Rajendranagar], Northern Telangana zone [rice-rice (14 years) cropping system at Regional Agricultural Research station, Jagtial], Godavari zone [rice-rice (26 years) cropping system at Andhra Pradesh rice Research Institute, Maruteru] and Scarce Rainfall Zone [groundnut fallow (30 years) cropping system at All India Co-ordinated Research Project on Dryland Agricultural Research Station, Ananthapur, The present study was carried out during *kharif* and *rabi* seasons of 2013–2014.

Computation of soil carbon stock

The size of total SOC stock estimation involves two steps [1]. The first step involves calculation of organic carbon (OC) by multiplying OC (g g⁻¹), bulk density (Mg m⁻³) and thickness of horizons (m) for individual soil profile with different thickness varying from 0-0.3, 0-0.5, 0-1.0, 0-1.5 m depth. In the second step the total SOC content determined by the first step was multiplied by the area (mha) of the soil unit. The total SOC is expressed in Pg (1 Pg = 10¹⁵ g = 1 billion tonne) as shown in the following equation.

$$\text{SOC stock in soils (Mg ha}^{-1}\text{)} = \text{C content} \times \text{BD} \times \text{area} \times \text{soil depth} \\ (\text{g g}^{-1}) (\text{Mg m}^{-3}) (\text{Mha}) (\text{m})$$

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For SIC, the same steps were followed using 12

Table 2. Long-term effects of INM treatments on soil inorganic carbon content (%) of the soils under different agro climatic zones.

Treatments	Southern Telangana Zone (Rajendranagar)		Northern Telangana Zone (Jagtial)	Godavari Zone (Maruteru)	Scarce Rainfall Zone (Ananthapur)
	Rice-Rice	Maize-Onion	Rice-Rice	Rice-Rice	Groudnut-fallow
Control	1.23	1.05	2.93	1.65	0.95
100% Inorganic	1.54 (25.2%)	1.52 (44.8%)	3.41 (16.4%)	1.96 (18.3%)	1.05 (10.5%)
100% Organic	–	1.80 (71.4%)	3.71 (26.6%)	2.41 (46.1%)	1.82 (91.6%)
50% Inorganic + 50% Organic	2.06 (67.5%)	2.25 (114.3%)	–	2.90 (75.8%)	2.40 (152.6%)
100% Inorganic + FYM @ 5 t ha ⁻¹	–	–	–	2.95 (78.8%)	–
100% Inorganic + FYM @ 10 t ha ⁻¹	–	–	3.90 (33.1%)	–	–

parts of C present in CaCO₃ values. The sum of SOC and SIC stock gave the total carbon (TC) stock in soils [6]. Carbon sequestration rate was calculated by dividing the carbon buildup or depletion with the age of the experiments in years and expressed as t ha⁻¹ yr⁻¹ [7].

Results and Discussion

The total carbon stock and carbon sequestration rate were significantly influenced by diversified crop management practices and long-term application of integrated nutrient management treatments are presented in tables 1 to 6.

Among the different Agro Climatic zones, Godavari Zone showed higher content of soil organic and inorganic carbon stock (38.07 and 7.17 Mg ha⁻¹, respectively) followed by Northern Telangana Zone (22.93 and 10.32 Mg ha⁻¹, respectively), Southern Telangana Zone (17.28 and 6.08) and Scarce Rainfall Zone (15.38 and 6.61). The result related to to-

tal carbon stock (Mg ha⁻¹) and carbon sequestration rate (Mg ha⁻¹ yr⁻¹) revealed that Godavari Zone recorded higher total carbon stock (45.12) and carbon sequestration rate (1.04) followed by Northern Telangana Zone (33.25 and 0.39) and Southern Telangana Zone (21.83, 0.70) whereas lowest was recorded under Scarce Rainfall Zone (20.63, 0.08). The treatment receiving inorganic fertilizers along with organic manures resulted higher amounts of total carbon stock in all the zones. The percent increase of total carbon stock over control was nearly 200, 100, 47, 31 and 22% in Godavari Zone, Southern Telangana zone (maize-onion), Scarce Rainfall Zone, Northern Telangana Zone and Southern Telangana Zone (rice-rice), respectively.

Carbon sequestration rate (Mg ha⁻¹ yr⁻¹) was higher in Godavari zone (-0.02 to 1.04), followed by Southern Telangana Zone (maize-onion) (-0.02 to 0.70), Northern Telangana Zone (0.02 to 0.39), Southern Telangana Zone (rice-rice) (0.03 to 0.16) and Scarce Rainfall Zone (0.01 to 0.13). Among the

Table 3. Long-term effects of INM treatments on soil carbon stocks (Mg ha⁻¹) of the soils under different agro climatic zones.

Treatments	Southern Telangana Zone (Rajendranagar)		Northern Telangana Zone (Jagtial)	Godavari Zone (Maruteru)	Scarce Rainfall Zone (Ananthapur)
	Rice-Rice	Maize-Onion	Rice-Rice	Rice-Rice	Groundnut-fallow
Control	13.68	8.10	17.64	10.73	11.48
100% Inorganic	16.32 (19.3%)	13.05 (61.1%)	19.40 (10%)	25.31 (135.8%)	13.31 (15.9%)
100% Organic	–	13.95 (72.2%)	22.27 (26.3%)	37.46 (249.1%)	15.38 (33.9%)
50% Inorganic + 50% Organic	17.28 (26.3%)	15.75 (94.4%)	–	38.07 (254.7%)	14.00 (21.9%)
100% Inorganic + FYM @ 5 t ha ⁻¹	–	–	–	32.00 (198.2%)	–
100% Inorganic + FYM @ 10 t ha ⁻¹	–	–	22.93 (30%)	–	–

Table 4. Long-term effects of INM treatments on soil inorganic carbon stocks (Mg ha^{-1}) of the soils under different agro climatic zones.

Treatments	Southern Telangana Zone (Rajendranagar)		Northern Telangana Zone (Jagtial)	Godavari Zone (Maruteru)	Scarce Rainfall Zone (Ananthapur)
	Rice-Rice	Maize-Onion	Rice-Rice	Rice-Rice	Groundnut-fallow
Control	3.54	2.84	7.75	4.01	2.62
100% Inorganic	4.44 (25.4%)	4.10 (44.8%)	9.02 (16.4%)	4.76 (18.7%)	2.89 (10.3%)
100% Organic	–	4.86 (71.1%)	9.82 (26.7%)	5.86 (46.1%)	5.01 (91.2%)
50% Inorganic + 50% Organic	5.93 (67.5%)	6.08 (114.1%)	–	7.05 (75.8%)	6.61 (152.3%)
100% Inorganic + FYM @ 5 t ha^{-1}	–	–	–	7.17 (78.8%)	–
100% Inorganic + FYM @ 10 t ha^{-1}	–	–	10.32 (33.2%)	–	–

treatments 50% organic + 50% inorganic treated plots showed higher sequestration rate than 100% organic and 100% inorganic treated plots (Table 6).

These results suggest that long-term application of organic manures alone or in combination with recommended dose of fertilizers have resulted in the buildup of soil organic carbon content even under tropical climate. The soils were rich in clay content (Godavari Zone and Northern Telangana Zone) and there was relatively higher soil organic carbon content [7]. Fine particle of the soil not only constitute simple (stocking compartment) for carbon [8] but also play a very important protective role for soil organic carbon as well as its coarse fraction associated with soil macro aggregates [9]. These results were in agreement with the earlier findings [10] [11] who reported changes in soil inorganic carbon, soil organic carbon, total carbon stock and carbon sequestration rate under long-term fertilizer experiments with various integrated nutrient management treatments.

It has been estimated that in Indian agroecosystem, 8-33% of added carbon was stabilized into soil organic carbon [12]. Variations in the carbon inputs into soil for different regions and cropping system suggest that wide variations in the rate of organic matter decomposition in soils under different climatic conditions of temperature, humidity, precipitation and acidity, prevailing at experimental sites. Hence, the above studies related to soil carbon sequestration and soil organic carbon pools showed both quantitative and qualitative responses to cropping systems and integrated nutrient management practices. The rate and magnitude of responses differed with soil types and inputs of carbon.

Application of recommended dose of fertilizer leads to carbon sequestration by increasing crop productivity and nutrient use efficiency. It has been showed that balanced application of NPK across the several sites in India improved soil organic carbon

Table 5. Long-term effects of INM treatments on total carbon stocks (Mg ha^{-1}) of the soils under different agro climatic zones.

Treatments	Southern Telangana Zone (Rajendranagar)		Northern Telangana Zone (Jagtial)	Godavari Zone (Maruteru)	Scarce Rainfall Zone (Ananthapur)
	Rice-Rice	Maize-Onion	Rice-Rice	Rice-Rice	Groundnut-fallow
Control	17.79	10.94	25.39	14.74	14.09
100% Inorganic	18.35 (3.1%)	17.15 (56.8%)	28.43 (11.9%)	30.08 (104.1%)	16.20 (14.9%)
100% Organic	–	18.81 (71.9%)	32.09 (26.4%)	43.32 (193.9%)	20.39 (44.7%)
50% Inorganic + 50% Organic	21.68 (21.9%)	21.83 (99.5%)	–	45.12 (206.1%)	20.61 (46.3%)
100% Inorganic + FYM @ 5 t ha^{-1}	–	–	–	39.16 (165.7%)	–
100% Inorganic + FYM @ 10 t ha^{-1}	–	–	33.25 (30.9%)	–	–

Table 6. Long-term effects of INM treatments on carbon sequestration rate ($\text{Mg ha}^{-1} \text{ yr}^{-1}$) of the soils under different agro climatic zones.

Treatments	Southern Telangana Zone (Rajendranagar)		Northern Telangana Zone (Jagtial)	Godavari Zone (Maruteru)	Scarce Rainfall zone (Ananthapur)
	Rice-Rice	Maize-Onion	Rice-Rice	Rice-Rice	Groundnut-fallow
Control	0.03	-0.02	0.02	-0.02	0.01
100% Inorganic	0.12	0.45	0.17	0.55	0.06
100% Organic	–	0.53	0.35	1.01	0.13
50% Inorganic + 50% Organic	0.16	0.70	–	1.04	0.08
100% Inorganic + FYM @ 5 t ha^{-1}	–	–	–	0.80	–
100% Inorganic + FYM @ 10 t ha^{-1}	–	–	0.39	–	–

content by 6–100% and carbon sequestration from 20–600 $\text{kg C ha}^{-1} \text{ yr}^{-1}$ depending upon soil, crop and climatic conditions [13]. Integration of inorganic fertilizer with organic sources such as FYM enhanced the soil organic carbon content by 17–100% and carbon sequestration from 100–1200 $\text{kg C ha}^{-1} \text{ yr}^{-1}$. In addition to this, being a source of carbon these organic manures improved soil aggregation and increase crop mediated carbon inputs through enhanced crop yield. further, addition of organic manures improved the macro aggregates and carbon storage inside the aggregates which was protected from decomposition [14].

Conclusion

The results related to total carbon stock (Mg ha^{-1}) and carbon sequestration rate ($\text{Mg ha}^{-1} \text{ yr}^{-1}$) revealed that Godavari Zone was recorded higher total carbon stock (45.12) and carbon sequestration rate (1.04) followed by Northern Telangana Zone (33.25 and 0.39) and Southern Telangana Zone (21.83, 0.70) whereas lowest was recorded under Scarce Rainfall zone (20.63, 0.08). The treatments receiving inorganic fertilizers along with organic manures resulted in higher amounts of total carbon stock in all the zones. however, percent increase of total carbon stock (Mg ha^{-1}) over control was highest in Godavari Zone (206) followed by Southern Telangana Zone (100), Scarce Rainfall Zone (46) and Northern Telangana Zone (31). Carbon sequestration rate ($\text{Mg ha}^{-1} \text{ yr}^{-1}$) was also higher in Godavari zone (1.04), followed by Southern Telangana zone (maize-onion) (0.70). Among the treatments 50% organic + 50%

inorganic treated plots showed higher sequestration rate than 100% organic and 100% inorganic treated plots. This indicates that combined application of organic and inorganic fertilizers helps in improving the soil carbon stocks. The total carbon stocks and carbon sequestration rate also increased with increase in application of organic matter.

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