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# Soil Organic Carbon Mapping and Estimation of Stock in Rice Soils of India

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## Abstract

Rice is the most important crop and lively hood for millions in India. It is widely cultivated in diverse ecologies and agro ecological zones. The differential paddy productivity across different rice growing environments in India is a potential threat for its sustainability. The present study is to develop Carbon maps and estimation of stock in rice soils of India under All India Coordinated Rice Improvement Programme (AICRIP). Soil samples from 0-10 and 10-20 cm depths were collected from >500 locations representing most of the rice growing districts from irrigated, rainfed shallow lowlands, deep water and upland/hilly land use systems. A large variation upto the tune of >70 % was noticed for soil organic carbon percentage and stocks among the four different rice ecologies. In the irrigated rice ecologies and more specially of the Indo-Gangetic Plains the decline in soil organic carbon was to the extent of 69.6% in comparison to the upland/hilly rice ecologies. This was closely followed in rainfed shallow lands where decline in soil organic carbon due to cultivation was to the tune of 67.0%. Decline of soil organic carbon in the surface soils of IGP plains of India is a cause of concern. Estimation of soil organic carbon status and its stock will be of immense benefit to the rice growers and its sustainability.

*Keywords: SOC, Irrigated , Rainfed shallow lowlands, GIS maps*

## Introduction, scope and main objectives

Rice is life in India and is grown in almost all the agro ecological regions. Worldwide, India stands first in rice area with 44.8 million hectares and second in production with 105 million tonnes after China. Within the country, rice is a major crop which accounts for 45.4% of area and 46.9% of total food grain production, thus playing a pivotal role in the food and livelihood security of the people. The diversity in the rice growing environments *viz*., water logged to rainfed uplands, jhums to deep water, high humid to arid temperatures and flood prone to drylands, wherein, irrigated ecology accounting for the largest area (24.5 m ha) and highest production (70.5 m t) and productivity (2.87 t/ha) closely followed by rainfed shallow lowlands. Rainfed upland, which accounts for nearly one fourth of the rainfed lowland area, records one seventh of production. Region wise, distribution pattern of rice growing districts based on productivity range reveal that of 563 districts, 115 districts (20.4%) contribute to 36.9 mt production with an average yield of 3.15 t/ha. Over 345 (61.3%) districts with yield levels less than that of the national average. Soils are varied extraordinarily in the country that there is hardly any type or texture of soils on which rice cannot be grown viz. acid peaty soils of Kerala (pH 3), highly alkaline soils (pH 8.5 & above) of Punjab, Haryana and Uttar Pradesh. The differential paddy productivity across different rice growing environment however, is often pointed and reasoned towards highly skewed and declining soil organic carbon status. The intensity and extent of nutrient stress concomitant with the loss of soil organic carbon in intensively cultivated areas makes it absolutely necessary, that the deficiencies and status of soil organic carbon of different soils are to be identified. This warrants a knowledge based alleviation and management of soils and inputs keeping in view the resource availability, cropping system, cropping intensity and nutrient flows in the system to economize input costs and improve factor productivity.

Soil carbon has received great attention during the development of the greenhouse gas (GHG) reporting programme of the IPCC since the mid-nineties. This was done to address the contribution of intensive land management and the vast amount of degraded land to GHG emissions, since these have caused tremendous historic losses of SOC, resulting in high potentials for future carbon storage. Recently, an increasing number of authors have stressed the crucial role of healthy soils, with soil carbon being the most important indicator, for food security and resilience against climate change. Hence, above and below ground carbon (SOC) became sub-indicators for SDG target 15.3 (degraded land). The renewed recognition of the central role of soil organic carbon as a basis for food security and their provision of key ecosystem services, including climate change adaptation and mitigation, has triggered numerous mapping projects across the globe.

At the same time, knowledge about SOC baselines and changes, and the location of vulnerable hot spots for SOC losses and gains under climate change and changed land management for all the rice ecologies of India is still fairly limited. Accurate baselines are still missing for all the rice ecologies of India, and estimates about the role of soils in the carbon cycle are still only based on rough estimates with large uncertainties. The present study, is an ongoing program of All India Coordinated Rice Improvement Programme (AICRIP) to develop soil quality maps of rice soils. **Carbon mapping and estimation of stock in rice soils of India** is being carried out to ascertain the role of carbon content in the soil, their depth wise stocks in all the major rice ecologies of India. This has an ultimate objective that better soil carbon management practices have potential to correct the existing differential paddy production pattern visible across different rice ecologies of India.

## Methodology

From the year 2014 onwards, triplicate soil samples from 0-10 and 10-20 cm depths were collected from all the rice ecologies covering entire geographical distribution of India where, rice is cultivated using a core sampler. Mean of soil samples collected constituted one replication (for statistical analyses). Similarly, soil samples from 0-10 and 10-20 cm depths were collected from >500 locations representing most of the rice growing districts from irrigated, rainfed shallow lowlands, deep water and upland/hilly land use systems. Thus, there were four land use systems/treatments considered for statistical analyses of all obtained data and three replications. The entire volumes of soils from each land use systems were meticulously mixed and representative samples were used for the analysis. Soil samples were then air-dried for a week, sieved through a 2 mm sieve, mixed and stored in sealed plastic jars for further analysis. Representative sub-samples were taken to determine various physico-chemical properties using normal protocols (Page et al., 1982).

### GIS based Soil Organic Carbon mapping and stocks estimation for rice soils of India

A district wise database was created for mapping of Soil carbon status and soil carbon stock. The database was joined to the digital map of India at district level (Survey of India- Everest India Geodetic coordinate system) and district wise maps were generated for Soil carbon and soil carbon stock using polygon symbology of ArcMap software (version 9.2). Secondary data on total rice area and rice area under irrigation were collected for the year 2009-10 (http://lus.dacnet.nic.in/). Rice area under the ecosystems like rainfed upland, low land and deep water were derived. Dot density map was generated to present district level irrigated, rainfed upland, lowland and deep water rice areas in India. The regular spacing of the dots in the map produces a visual display of denser pattern of dots representing the density of rice area under different ecosystems.

Soil carbon and soil carbon stock maps were overlaid with rice area under different ecosystems map to study the soil carbon and SC stock under different ecosystems of rice crop(Fig 1). We analysed soil properties using ANOVA for a randomized block design (with four treatments and three replications). Tukey's honestly significant difference test was used as a *post hoc* mean separation test ($P < 0.05$) using SAS 9.1 (SAS Institute, Cary, North Carolina, USA). Statistical analysis were carried out at all depths within a land use and the differences were considered significant when $P < 0.05$.

**Results**

This is a first attempt to characterize the rice ecologies for its soil organic carbon and their stocks. A large variation up to the tune of >70 % was noticed for soil organic carbon percentage and stocks among the four different rice ecologies. This ongoing study indicated that decline in surface soil organic carbon in the rice ecologies of India reduced two times faster than that of the soil carbon storage in the upland/hilly rice ecologies. In the irrigated rice ecologies and more specially of the Indo-Gangetic Plains the decline in soil organic carbon was to the extent of 69.6% in comparison to the upland/hilly rice ecologies. This was closely followed in rainfed shallow lands where decline in soil organic carbon due to cultivation was to the tune of 67.0%. Invariably, cultivation leads to decline in soil organic carbon in the range of 19-70% from the initial value. It is particularly to be noticed that the agricultural soils of northwest India exclusive of the Himalayas have lost about one half to two thirds of their original organic carbon content. In the different ecology wise studies, the mean surface soils carbon content of irrigated areas was 0.39 % and it ranged from 0.13% to 0.78%.

Mean bulk density in the plots under irrigated rice ecologies (1.06 Mg $m^{-3}$) was significantly higher than the upland/hilly rice ecologies (0.92 Mg $m^{-3}$). Rainfed shallow lowlands had the highest mean average bulk density (1.23 Mg $m^{-3}$). Irrespective of the land use systems, soil bulk density augmented with soil depth. Soil bulk density values for different depths among the rice ecologies systems were non-significant. However, down the profile bulk density values increased due to more compaction in the soil strata.

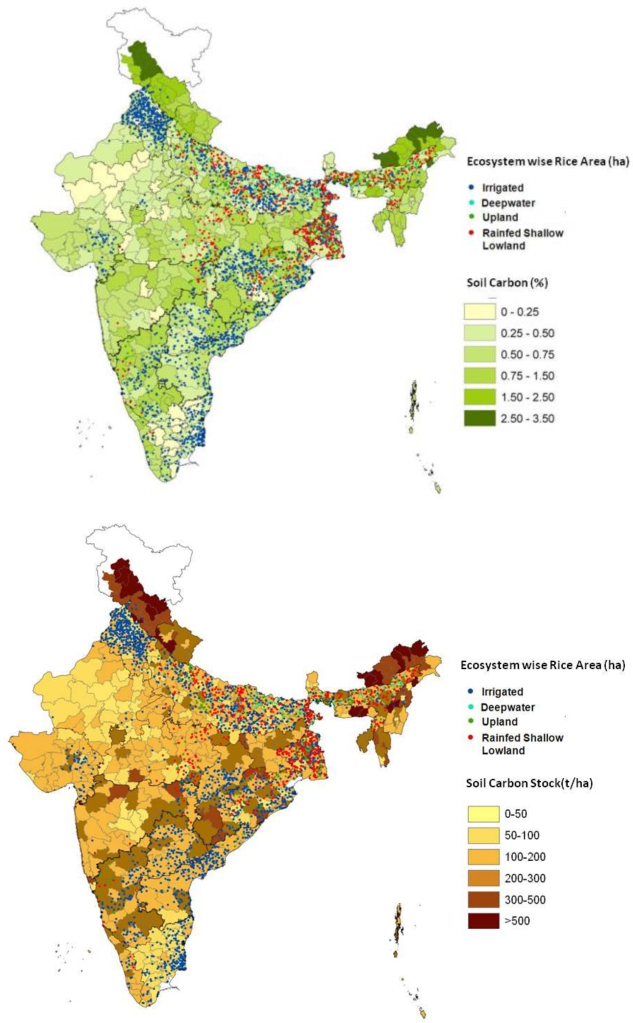


**Fig. 1: First map showing Soil Carbon status in 0-20cm depth and the second map depicts the soil organic carbon stock in the same depth in all the rice ecologies of India**

## Discussion

Districts falling under irrigated rice ecologies and districts under shallow lowlands had almost similar decline in mean SOC values and had higher SOC contents in the sub-surface soil layer than the surface layer (0-20 cm). Mean SOC stock was highest in the districts under upland/hilly rice ecologies.

This is especially true because there are large carbon storage potentials due to unsustainable management, land-use change and land degradation; increasing SOC levels also improve the resilience of soils to climate change effects (e.g. drought; increased SOC improves various soil functions including water holding capacity and nutrient availability). Efforts to increase SOC by increasing organic matter levels in soils require baseline data (location of degraded sites, hot spots for restoration) in order to plan action on the ground, and monitoring in order to verify that the intended effects are achieved. Soil carbon sequestration through the restoration of soil organic matter can further reverse land degradation and restore soil “health” through improved soil water storage and nutrient cycling, land use practices that sequester carbon will also contribute to stabilizing or enhancing food production and optimizing the use of synthetic fertilizer inputs, thereby reducing emissions of nitrous oxides from agricultural land.

**Conclusions**

This is a first attempt to characterize the rice ecologies for its soil organic carbon and their stocks. The SOC status often found to decrease sharply with soil depth in each of the selected rice ecologies. Large variation up to the tune of >70 % was noticed for soil organic carbon percentage and stocks among the four different rice ecologies. Mean bulk density in the plots under irrigated rice ecologies (1.06 Mg $m^{-3}$) was significantly higher than the upland/hilly rice ecologies (0.92 Mg $m^{-3}$). Rain fed shallow lowlands had the highest mean average bulk density (1.23 Mg $m^{-3}$). This had an influence on estimation of soil organic carbon stocks in 0-20cm depths. Decline of soil organic carbon in the surface soils of IGP plains of India is a cause of concern. Rehabilitation measures are the need of the hour for vast areas of slash and burn cultivation in the hilly region of North eastern regions of India.