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## Effect of crop management practices on soil's carbon pool index, lability index and carbon management index under cotton based intercropping system in Vertisol

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### Abstract

Effect of crop management practices on soil's carbon pool index, lability index and carbon management index under cotton based intercropping system in Vertisol was investigated during 2015-16 and 2016-17 on Research Farm, Department of Soil Science and Agriculture Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The treatments comprised of control (only cotton), and cotton based intercropping systems viz. cotton + dhaincha (1:1), cotton + sunhemp (1:1), cotton + green gram (1:1), cotton + cow pea (1:1), cotton + black gram (1:1), cotton + pigeon pea (6:2) and cotton + soybean (1:1) which were executed in randomized block design with three replications. The *in situ* incorporation of dhaincha in cotton + dhaincha intercropping system recorded improvement in physical, chemical and biological properties. Various carbon pools and soil organic carbon stock was registered highest under cotton + dhaincha (1:1) intercropping system which helped to improve carbon lability index, carbon pool index as well as carbon management index.

**Keywords:** Carbon pool, dhaincha, carbon stock, intercropping system

### Introduction

World soils play an important role in the global C cycle. The soil C stock comprises of two related but distinct components: soil organic C (SOC) and soil inorganic C (SIC). The global SOC stock (Pg = 1 billion ton = Gt) is estimated at 704 for 0.3m, 1505 for 1m and 3300 for 2m depth. The SIC stock (Pg) is estimated at 234 for 0.3m, 722 for 1m, and 1700 for 2m depth. Thus, total soil C stock to 2m depth is 5000 Pg. In addition, soils of the permafrost contain 1400-1700Pg. Thus, total soil C stock of ~6500 Pg is 8.1 times the atmospheric C stock of 800 Pg and 10.5 times that of the biotic C stock (620 Pg) (Lal, 2018) <sup>[10]</sup>. Soil can be a source or sink of atmospheric CO<sub>2</sub> depending upon land use and management. Conversion of natural into managed (agricultural, urban, etc.) ecosystems can deplete the SOC stock. The magnitude of depletion depends on the historic land use management and vulnerability to erosion and other forms of degradation. The important constraints in semi-arid regions for maintenance of soil organic carbon in soils are prevailing high temperatures coupled with prolong dry spells. The situation is being further aggravated by the effects of climate change which needs systematic strategies.

Soils of managed ecosystems and those prone to degradation and depletion have a potential C sink capacity. The strategy to recarbonization of the soil is based on the concept of creating a positive soil C budget. This implies that input of Biomass-C into the soil (e.g. crop residues return, cover cropping, manuring) exceeds the losses caused by erosion, decomposition and leaching (Lal, 2018) <sup>[10]</sup>. Managing soils for increasing C stock called "soil C sequestration" refers to that of SOC or SIC, within a landscape unit sequestration of SOC is a preferred option in humid, sub-humid and semi-humid climates. However, sequestration of SIC as secondary carbonates or leaching of bicarbonates can be an option in arid and semi-arid regions and in irrigated soils. Techniques of SOC sequestration include conservation agriculture, cover cropping, agroforestry, controlled grazing, improved pastures, integrated nutrient management, biochar etc. (Lal, 2018) <sup>[10]</sup>. The rate of SOC sequestration may range from 0.1 to 1.0 MgC/ha/yr. depending on climate, soil and land use. The rate of SIC sequestration as secondary carbonates may be 2-5 kg/ha/yr (Lal, 2018) <sup>[10]</sup>.

Agronomic and environmental benefits associated with the build-up of soil organic matter (SOM) stock are widely appreciated and have been documented in many studies. Albrecht (1938) [1] stated that soil organic matter is one of our most important national resources, its unwise exploitation has been devastating, and it must be given proper rank in any natural resource management related policy as one of the major factors affecting the level of crop production in the future. Soil organic matter is a primary indicator of soil quality (Larson and Pierce, 1994) [11] and the amount and quality of SOM impacts soil biological activity, soil structure and water dynamics, nutrient cycling and availability and global C cycle. Soil organic matter serves both as a source and a sink for major and micro nutrients and is thus a fundamental component of soil fertility that plays pivotal role in crop production.

Cotton is one of the most important fiber and cash crop of India. It plays a key role in Indian economy. It is globally known as 'king of fiber' cotton seed contain 15-20% oil and used as vegetable oil in soap industries. The left over cake, a byproduct of cotton mill is very important feed for livestock. In India, cotton is grown on 122.38 lakh ha area, with 361 lakh bales production and 501 kg ha<sup>-1</sup> yield. In Maharashtra, it is grown on 41.19 lakh ha area with 81.00 lakh bales production and 334 kg ha<sup>-1</sup> yield (Anonymous, 2018) [2]. The reasons for low productivity includes erratic distribution of rainfall, imbalanced fertilizer use, poor quality seed, low adoption of improved agro-techniques and decline in soil health therefore adoption of proper crop management strategies is necessary to increase productivity and fertility of soil by increasing soil carbon sequestration under cotton based intercropping system. The amount of SOC declines (Arrouays and Pelisser, 1994) [3] when the land area under agricultural activity is increased to produce more food grains.

Change in land use contributes C to the atmosphere in two principal ways: (i) release of C in the biomass which is either burnt or decomposed, and (ii) release of soil organic carbon (SOC) following cultivation due to enhanced mineralization brought about by change in soil moisture and temperature regimes and low rate of return of biomass to the soil. The potential of biomass addition under various intercropping is variable and needs to be taken into account for carbon sequestration in soil. The day by day decline in SOC leading to poor soil health, it is necessary to adopt proper intercropping in soil health point of view and the impact of crop management practices on soil's carbon pool index, lability index and carbon management index needs to be ascertained under cotton based intercropping system in Vertisol.

### Material and Method

The field experiment was conducted on Research Farm, Department of Soil Science and Agriculture Chemistry, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. There were eight treatments with three replications in randomised block design located at 22.42°N latitude and 77.02°E longitude at an altitude of 307.42 m above the mean sea level and has a subtropical climate. The soil of the experimental site was clayey in nature slightly alkaline having pH 8.02 (Jackson, 1973) [9], non – saline with medium calcareous (Jackson 1973) [9] and moderate in soil organic carbon (Jackson 1973) [9]. Soil fertility status indicated low in available nitrogen (Subbiah and Asija 1956) [15], medium in available phosphorous (Watanabe and Olsen, 1965) [17], high in available potassium (Jackson 1973) [9] and medium in available sulphur (Chesnin and Yien, 1951) [6]. In case of micronutrients sufficient in DTPA – Zinc, iron, manganese and copper (Lindsay and Norvell 1978) [12] at the start of experiment shown in Table 1.

**Table 1:** Physical and chemical properties of soils at experimental site (Kharif, 2015-16)

| Sr. No.                       | Particulars                                   | Value  |
|-------------------------------|---|--------|
| <b>A. Physical properties</b> |   |        |
| 1                             | Bulk density (Mg m <sup>-3</sup> )            | 1.36   |
| 2                             | Mean weight diameter (mm)                     | 0.60   |
| 3                             | Hydraulic conductivity (cm hr <sup>-1</sup> ) | 0.68   |
| <b>B. Chemical properties</b> |   |        |
| 1                             | pH (1:2.5)                                    | 8.02   |
| 2                             | EC (dS m <sup>-1</sup> )                      | 0.44   |
| 3                             | CaCO <sub>3</sub> (%)                         | 7.60   |
| 4                             | Organic carbon (g kg <sup>-1</sup> )          | 6.10   |
| 5                             | POC (mg kg <sup>-1</sup> )                    | 116.30 |
| 6                             | Available nitrogen (kg ha <sup>-1</sup> )     | 188.97 |
| 7                             | Available phosphorus (kg ha <sup>-1</sup> )   | 15.99  |
| 8                             | Available potassium (kg ha <sup>-1</sup> )    | 328.16 |
| 9                             | Available sulphur (mg kg <sup>-1</sup> )      | 10.05  |
| 10                            | DTPA Zn (mg kg <sup>-1</sup> )                | 0.61   |
| 11                            | DTPA Fe (mg kg <sup>-1</sup> )                | 5.80   |
| 12                            | DTPA Mn (mg kg <sup>-1</sup> )                | 15.30  |
| 13                            | DTPA Cu (mg kg <sup>-1</sup> )                | 2.23   |

The experiment was laid out in a randomized block design (RBD) on the same site with three replications having eight treatments, namely T<sub>1</sub> - control (only cotton), T<sub>2</sub> - Cotton + Dhaincha (1:1), T<sub>3</sub> - Cotton + Sunhemp (1:1), T<sub>4</sub> - Cotton + Green gram (1:1), T<sub>5</sub> - Cotton + Cow pea (1:1), T<sub>6</sub> - Cotton + Black gram (1:1), T<sub>7</sub> - Cotton + Pigeon pea (6:2), T<sub>8</sub> - Cotton + Soybean (1:1). Sowing of cotton was done at 90 X 45 cm spacing. Intercrops were grown in between two rows of cotton crops. The *in situ* incorporation of dhaincha and sunhemp was done 45 and 30 days after sowing respectively. The

incorporation of green gram, cow pea, black gram and soybean was done after pod picking. Shaded leaf litter biomass of pigeon pea was recorded. The intercrops samples were collected before its incorporation and analysed in laboratory. The weight of biomass of intercrops on green basis and oven dry basis were recorded. Among all the intercrops the highest average dry biomass was observed by dhaincha (23.72 q ha<sup>-1</sup>) followed by sunhemp (21.86 q ha<sup>-1</sup>), cowpea (19.78 q ha<sup>-1</sup>), soybean (17.22 q ha<sup>-1</sup>) and black gram (16.60 q ha<sup>-1</sup>). The nitrogen, phosphorus and potassium

nutrients were applied through fertilizers *viz.*, urea, single super phosphate (SSP) and muriate of potash containing 46, 16.0 and 60 per cent N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O respectively. The recommended dose for cotton @ 100 per cent was 60:30:30 N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O kg ha<sup>-1</sup>. The basal dose was applied as 50%N and 100% P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O was applied at the time of sowing and remaining 50 % N was applied after 30 DAS.

### Carbon management index (CMI)

Carbon management index is sensitive and useful index for assessing and monitoring the dynamics of soil organic carbon under different intercropping system. CMI was determined by the formula

$$\text{CMI} = \text{CPI} \times \text{LI} \times 100$$

Where, CPI is the carbon pool index and LI is the lability index.

### Lability index (LI)

LI for SOC was computed using all the three labile fractions (VLC, LC and LLC) as proposed by Chan *et al.* (2001) [5]. The VLC, LC and LLC have been designated as very labile, labile and less labile and are given weightage of 3, 2 and 1, respectively.

$$\text{Lability Index (LI)} = \text{VLC/TOC} \times 3 + \text{LC/TOC} \times 2 + \text{LLC/TOC} \times 1$$

### Carbon pool index (CPI)

CPI was derived using the formula:

$$\text{CPI} = \frac{\text{Sample total carbon (g kg}^{-1}\text{)}}{\text{Reference total carbon (g kg}^{-1}\text{)}}$$

Where, reference total carbon is the total carbon content (TOC, g kg<sup>-1</sup>) of barren soil.

## Results and Discussion

### Carbon pool index (CPI)

The carbon pool index of soil was calculated by taking total carbon content of treated soil with reference to total carbon content of barren soil. The CPI varied from 0.963 to 0.990 during first year and 0.980 to 1.04 during second year. CPI of soil was observed non-significant results during first year while significantly highest carbon pool index was emanated with the treatment of cotton + dhaincha (1:1) intercropping system (1.04) which was observed at par with cotton + sunhemp (1:1) intercropping system (1.02), cotton + pigeon pea (6:2) intercropping system (1.02) (Table 2)

### Carbon lability index (LI)

Carbon lability index for SOC was computed using all the three labile fractions (VLC, LC and LLC) as proposed by Chan *et al.* (2001) [5]. The VLC, LC and LLC have been designated as very labile, labile and less labile and are given weightage of 3, 2 and 1, respectively. Subsequently, their actual values are transformed to a proportional amount of

TOC and weighted with the weighing factor to get a LI for the organic C content in soils under different intercropping system. The LI thus obtained is compared for studying relative performance of different intercropping systems particularly in maintaining labile soil organic C.

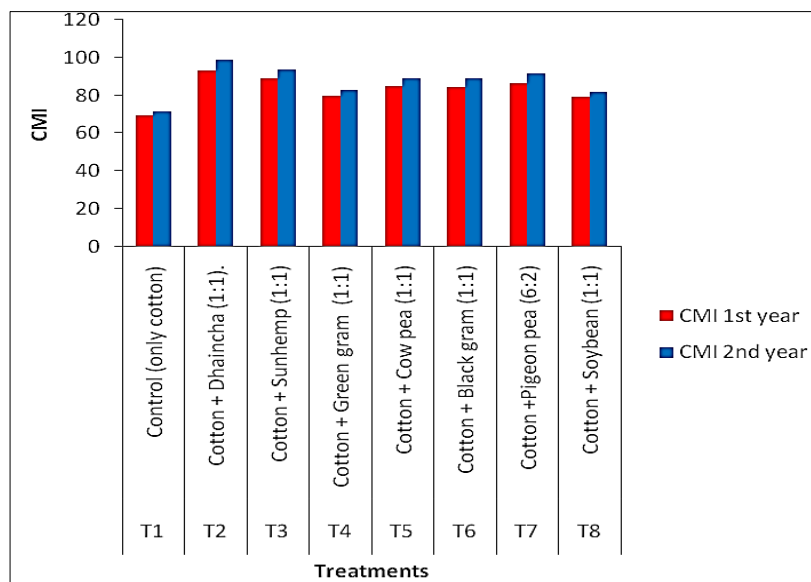
The LI of soil varied from 0.72 to 0.94 during first year and 0.73 to 0.95 during second year (Table 2). LI of soil was found significantly influenced during both the years. Significantly highest carbon lability index was estimated with the treatment of cotton + dhaincha (1:1) intercropping system (0.94) during both the years which was observed at par with cotton + sunhemp (1:1) intercropping system (0.90), cotton + pigeon pea (6:2) intercropping system (0.88), cotton + cow pea (1:1) intercropping system (0.87) and cotton + black gram (1:1) intercropping system (0.87) in first year whereas, during second year it was observed at par with cotton + sunhemp (1:1) intercropping system (0.92), cotton + pigeon pea (6:2) intercropping system (0.90), cotton + black gram (1:1) intercropping system (0.90), cotton + cow pea (1:1) intercropping system (0.89) and cotton + green gram (1:1) intercropping system (0.84).

The recalcitrant C pool altered slowly by microbes and contributes significantly to SOC sequestration. Recalcitrant C includes lignin, tannin, humified protein, cutans, suberans, sporopollenins etc. Apparently, the organics, having a narrower C:N ratio encouraged accumulation of labile (VLC and LC) fractions of soil organic carbon, whereas materials with a wider C:N ratio improved relatively recalcitrant carbon (LLC and NLC) fractions.

The C:N ratio of all *in situ* incorporated intercrops i.e., dhaincha, sunhemp, green gram, black gram, cow pea, soybean and shaded leaf litter of pigeon pea were narrower so that it helps to enhance very labile carbon and labile carbon pools (Active pool) in soil. Lower value of non-labile carbon were registered in all cotton based intercropping system accept sole cotton might be due to recent start of experiment since two years. The findings are in line with the results reported by Mandal *et al.* (2011) [3], Das *et al.* (2016) [7].

### Carbon management index (CMI)

The carbon management index (CMI) is a sensitive and useful index for assessing and monitoring the dynamics of SOC under different crop management practices relative to a more stable reference soil (Blair *et al.* 1995) [4]. The CMI, which depends on both total carbon and labile carbon, measures soil sustainability (sustainable if CMI >100 %). The CMI was determined according to the mathematical procedures used by Blair *et al.* (1995) and Venkatesh *et al.* (2013) [4, 6]. (Table 2 and fig.1). The CMI of soil varied from 69.34 to 93.06 during first year and 71.54 to 98.80 during second year. Significantly highest carbon management index was registered with the treatment of cotton + dhaincha (1:1) intercropping system (98.80) which was observed at par with cotton + sunhemp (1:1) intercropping system (93.84), cotton + pigeon pea (6:2) intercropping system (91.80), cotton + cow pea (1:1) intercropping system (89.00) and cotton + black gram (1:1) intercropping system (89.10) during both the years of experiments.



**Fig 1:** CMI under various treatments

The CMI compares the changes that occur in total and LC as a result of agricultural practices, with an emphasis on the changes in LC, as opposed to NLC in soil organic matter. Therefore, the integration of both soil organic C pool and C lability into the CMI can provide a useful parameter to assess the capacity of management systems to promote soil quality (Blair *et al.* 1995) <sup>[4]</sup>. A management system is considered sustainable, if the CMI value is greater than 100. The CMI under different intercropping systems was followed the order: cotton + dhaincha (1:1) intercropping system (93.06) > cotton + sunhemp (1:1) intercropping system (88.92) > cotton + pigeon pea (6:2) intercropping system (86.59) > cotton + cow pea (1:1) intercropping system (84.74) > cotton + black gram (1:1) intercropping system (84.65) > green gram (1:1) intercropping system (79.79) > soybean (1:1) intercropping system (79.06) > control (only cotton) (69.34) during first year.

While during second year cotton + dhaincha (1:1) intercropping system (98.80) > cotton + sunhemp (1:1) intercropping system (93.84) > cotton + pigeon pea (6:2) intercropping system (91.80) > cotton + black gram (1:1) intercropping system (89.10) > cotton + cow pea (1:1) intercropping system (89.00) > cotton + green gram (1:1) intercropping system (83.16) > cotton + soybean (1:1) intercropping system (82.00) > control (only cotton) (71.54).

The percent increase of CMI under different intercropping systems followed the order: cotton + dhaincha (1:1) intercropping system (45.89 %) > cotton + sunhemp (1:1)

intercropping system (38.57%) > cotton + pigeon pea (6:2) intercropping system (35.56%) > cotton + black gram (1:1) intercropping system (31.57%) > cotton + cow pea (1:1) intercropping system (31.42%) > green gram (1:1) intercropping system (22.80 %) > cotton + soybean (1:1) intercropping system (21.09 %) > control (only cotton) (5.64%) over initial CMI.

Similar study observed by Moharana *et al.*, (2017) <sup>[14]</sup> observed that CMI under different systems was followed the order: wheat–pearl millet (299) > wheat–green gram (251) > chickpea–groundnut (220) > mustard–moth bean (169) > barley–fallow (147) > fallow (114) > barren (91) (Figure 3(c)). Improvement in CMI value under high cropping intensity over barren could be attributed to addition of organic carbon through root biomass. The higher values of CMI indicates that the system have greater soil quality than the other management systems.

Improvement in CMI under cotton + dhaincha (1:1) intercropping system over control (only cotton) could be attributed to addition of organic carbon through incorporation of dhaincha which helps to increase the biomass of cotton crop by supplying proper nourishment to crop. The higher CMI indicates that the system have greater soil quality than the other crop management systems. As the experiment has been started only from 2 years the CMI not observed more than 100, but as the year passes there is a scope to cross CMI more than 100 to establish sustainable intercropping system in future.

**Table 2:** Effect of crop management strategies on carbon pool index, lability index and carbon management index under cotton based intercropping system

| Treatments     |                           | Carbon pool index |         | Lability index |         | Carbon management index |         |
|----------------|---------------------------|-------------------|---------|----------------|---------|-------------------------|---------|
|                |                           | 2015-16           | 2016-17 | 2015-16        | 2016-17 | 2015-16                 | 2016-17 |
| T <sub>1</sub> | Control (Only cotton)     | 0.963             | 0.98    | 0.72           | 0.73    | 69.34                   | 71.54   |
| T <sub>2</sub> | Cotton + Dhaincha (1:1).  | 0.990             | 1.04    | 0.94           | 0.95    | 93.06                   | 98.80   |
| T <sub>3</sub> | Cotton + Sunhemp (1:1)    | 0.988             | 1.02    | 0.90           | 0.92    | 88.92                   | 93.84   |
| T <sub>4</sub> | Cotton + Green gram (1:1) | 0.973             | 0.99    | 0.82           | 0.84    | 79.79                   | 83.16   |
| T <sub>5</sub> | Cotton + Cow pea (1:1)    | 0.974             | 1.00    | 0.87           | 0.89    | 84.74                   | 89.00   |
| T <sub>6</sub> | Cotton + Black gram (1:1) | 0.973             | 0.99    | 0.87           | 0.90    | 84.65                   | 89.10   |
| T <sub>7</sub> | Cotton + Pigeon pea (6:2) | 0.984             | 1.02    | 0.88           | 0.90    | 86.59                   | 91.80   |
| T <sub>8</sub> | Cotton + Soybean (1:1)    | 0.976             | 1.00    | 0.81           | 0.82    | 79.06                   | 82.00   |
| SE(m)±         |                           | 0.06              | 0.008   | 0.02           | 0.04    | 3.44                    | 3.37    |
| CD at 5%       |                           | NS                | 0.02    | 0.08           | 0.12    | 10.44                   | 10.24   |
| Initial        |                           | 0.956             |         | 0.71           |         | 67.72                   |         |



## Conclusion

From the present investigation, it is concluded that, Cotton + dhaincha (1:1) intercropping system enhanced total organic carbon, soil organic carbon stock, soil carbon pools, lability index and carbon management index in soil.

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