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Land use systems to improve carbon sequestration in soils for mitigation of climate change

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Abstract
The main objective of this study was to assess the carbon stocks and carbon dioxide sequestration under different land use systems within the same locality with four old cultivation. The soil samples were collected at a depth of 0-15cm, 15-30cm, 30-50 cm and 50-100 cm from a mango, cashew, rose, vegetable and medicinal and aromatic cropping systems. The study showed that, the magnitude of carbon sequestration is more under mango orchard followed by cashew orchard than annuals crops like rose, medicinal and aromatic and vegetable block. The carbon dioxide sequestration was significantly greater under the perennial crops as compared to annual crops. It was observed that perennial horticulture crops increases the soil organic carbon (SOC) and carbon dioxide storage than annual crops and reduce the carbon emissions to the atmosphere which helps to mitigate the global warming.

Keywords: carbon storage, carbon dioxide sequestration, climate change, land use systems

1. Introduction

Carbon sequestration by terrestrial ecosystem is the net removal of carbon dioxide (CO_2) gas from the atmosphere or the avoidance of its emissions from terrestrial ecosystems into the atmosphere. The removal process include: CO_2 uptake from the atmosphere by green plants through photosynthesis and the carbon stored as plant biomass (in the trunks, branches, leaves and roots of the plants) and organic matter in the soil. Soil carbon sequestration involves adding the maximum possible organic carbon to the soil. The carbon dioxide gas is a major cause of the atmospheric greenhouse effect and hence can influence the global climate. However, many other gases such as methane (CH_4), ozone (O_3) and nitrous oxide (N_2O) influence the global climate. Carbon sequestration studies have gained momentum in the recent decade and the amount of carbon stored in a system is a good measure of its sustainability. Most of the factors affecting carbon sequestration are affected by land management practices. The distortion in the global carbon balance through human activities is due to the burning of fossil fuel and agriculture and land use change (33%). Actions to sequester carbon in the soils will generally increase the organic matter content of soils. Soil organic carbon, as reported by Bationo *et al.,* is simultaneously a source and sinks for nutrients and plays a vital role in soil fertility maintenance.

Growing of perennial horticulture crops is one of the strategies to improve soil conditions which would result in enhancing soil attributes and contributing to the good soil health and helps to sequester more organic carbon and carbon dioxide in soil as compared to annual crops. Although the benefits of perennial horticulture crops on soil in improving its chemical properties have been well known, but the present study is a modest attempt to assess the carbon storage and carbon dioxide sequestration under diverse horticultural cropping systems within the same locality of four year old cultivation *i.e.,* annuals *vis-a vis* perennial crops. The hypothesis of the study was that, land use systems sequester SOC and CO_2 differently.

2. Materials and Methods

The investigation was carried out at the Regional Horticultural Research and Extension Centre, UHS Campus GKVK, Bengaluru, Karnataka during 2015. The soil of the experimental site is sandy loam and classified as fine, mixed isothermic Kandic Paleustalf of Vijayapura soil series. Cultivation of selected horticulture crops for experiment *viz.,* mango, cashew, rose, vegetables and medicinal and aromatic crops was started in the year 2010. The experiment plots were permanently laid out for specified crops. In each sampling site, soil samples were collected from four different depths *i.e.,* 0-15, 15-30, 30-50, and 50-100 cm.

The study was carried out in a Randamized Complete Block Design (RCBD).
Soil samples were processed by drying under the shade, powdering with a clean wooden mallet and passing through a 2 mm sieve. The processed samples were stored in polyethylene bags for analysis in the laboratory. For determination of organic carbon, a small volume of stored sample was further ground and passed through a 0.2mm sieve before analysis and soil organic carbon (SOC) was determined by the modified Walkley and Black dichromate digestion method.

2.1 Calculation of the organic carbon sequestered (stored)
The SOC stored was calculated using the Donovan formula.

$CT = CF \times D \times V$

Where:
CT is the total carbon stored per area in Mg ha^{-1}
CF is the fraction SOC (percentage carbon divided by hundred),
D is the soil bulk density and
V is the volume of the soil in cubic meters (which is = Depth of soil x area of soil)

2.2 Conversion of soil organic carbon to CO_2
The final results were multiplied by a factor of 3.67 (*i.e.* the molecular mass of CO_2/ atomic mass of C) to convert the total carbon stored to carbon dioxide.

3. Results and Discussions
3.1 Soil organic carbon under different land use systems
Organic carbon content at different depths as influenced by different horticulture crops is presented in figure1.

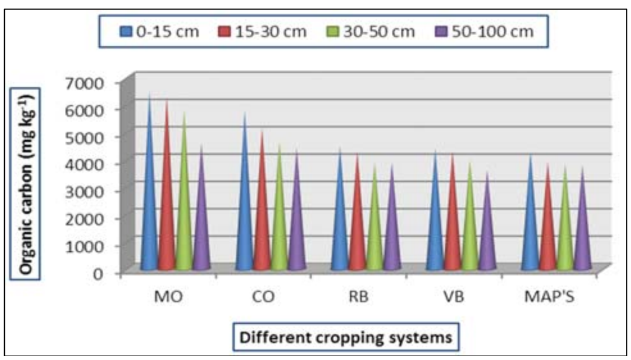

Fig 1: MO- Mango Orchard, VB- Vegetable Block, CO- Cashew Orchard, MAP's- Medicinal and Aromatic Plants, RB- Rose Block.

The organic carbon content of soil was higher in the surface layer of the soil *i.e.,* 0-15 cm as compared to other subsurface soil depth in all the cropping systems and the organic carbon content decreased with increase in soil depth. The carbon content differed significantly with different cropping system, the mango orchard had higher organic carbon content *i.e.,* 6500.00, 6316.00, 5846.00, and 4611.00 mg kg^{-1} at 0-15 cm, 15-30 cm, 30-50 cm and 50-100 cm depths respectively which was followed by cashew orchard whereas, the medicinal and aromatic block had lowest organic carbon 4300.00, 3916.00, 3834.00 and 3786.00 mg kg^{-1} at 0-15 cm, 15-30 cm, 30-50 cm and 50-100 cm depths respectively.
This is due to the continuous addition of organic matter by continuous falling of leaves in perennials crops like mango and cashew orchard leads to accumulate more organic matter to the soil.
Since organic manures are incorporated in to the surface and a major portion of the left over residues of shallow rooted crops usually accumulate in the top few centimetre of the soil layers, there was possibility for a relatively greater accumulation of organic carbon in 0-15 cm soil as compared to the soils of lower layer. Similar results were obtained by Manjaiah *et al*. (2000). Increase in soil carbon due to continuous addition of bio mass through leaf and roots have been reported by Geo Jose (2006) in case of field crops and by Krishnappa Naik *et al*. (1998).

3.2 Bulk density under different land use systems
Bulk density at different depths as influenced by different horticulture crops is presented in figure 2.
Bulk density of the soil changed significantly over years of cultivation of perennial and annual crops. It was found that the higher bulk density values were recorded in the subsurface layers of the soil as compared to surface layers and it was observed that bulk density was increased with increase in soil depth.

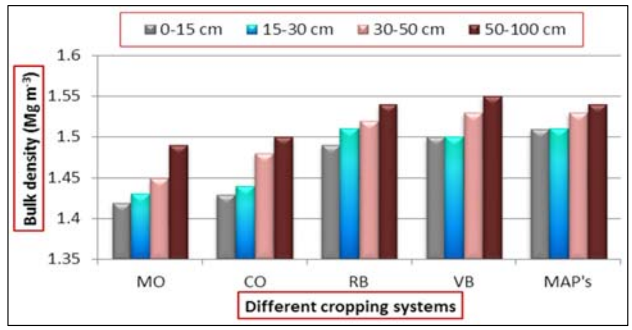

Fig 2: MO- Mango Orchard, VB- Vegetable Block, CO- Cashew Orchard, MAP's- Medicinal and Aromatic Plant, RB- Rose Block.

The annual crops like, vegetable block had higher bulk density (1.55Mg cm^{-3}) followed by medicinal and aromatic block (1.54 Mg cm^{-3}) and significantly lowest values were recorded under the mango orchard (1.49Mg cm^{-3}) at 50-100cm soil depth. This is due to the continuous addition of organic matter with minimum tillage treatments under perennial crops reduces the breakdown of soil aggregates which helps to reduce the bulk density. However, in case of annual crops due to continuous cultivation, the soil aggregates are broken down into small soil particles, as the size of the soil particles decreases the bulk density increases.

3.3 Soil carbon storage/stocks under different land use systems
The carbon stocks differed at different depth. The higher carbon stocks was observed in the subsurface layer *i.e.,* 50-100 cm and lowest was observed in 0-15 cm, 15-30 cm and 30-50 cm soil depths. The carbon stocks were increased with increase soil depth. Among different cropping systems, the mango orchard had maximum carbon stocks (4478.19Mg ha^{-1}) which is on par with the cashew orchard (4075.50Mg ha^{-1}) and significantly lowest values was observed under the medicinal and aromatic block (3082.30Mg ha^{-1}). In an one meter soil depth, the mango orchard sequestered maximum carbon content (9025.38Mg ha^{-1}) which was followed by cashew orchard (8244.12Mg ha^{-1}) and lowest organic carbon was sequestered under the medicinal and aromatic block (6275.49Mg ha^{-1}).
Soil carbon storage at different depths as influenced by different horticulture crops is presented in Table 1.

Horticulture land use system	4 year old cultivation				
	Carbon stocks (Mg ha^{-1})				
	0-15 cm	15-30 cm	30-50 cm	50-100 cm	Total (1 m depth)
Mango orchard	1374.75	1361.20	1811.24	4478.19	9025.38
Cashew orchard	1244.10	1245.02	1679.50	4075.50	8244.12
Rose block	1005.75	1003.62	1305.90	3215.22	6530.49
Vegetable block	990.00	973.35	1308.40	3110.07	6381.92
Medicinal and aromatic block	973.95	954.24	1265.00	3082.30	6275.49
SEm ±	62.22	61.45	81.56	199.45	405.45
CD at 5%	186.25	184.56	245.55	599.56	1215.66

The carbon stocks were higher under the perennial horticulture crops as compared to annual crops. This is due to the continuous addition of organic matter under perennial crops which leads to continuous decomposition of the accumulated organic matter under the system. The thick litter also reduced the amount of CO_2 gas emitted into the atmosphere. The implication is that, crop residue application as surface mulch could play an important role in the maintenance of soil organic carbon levels and productivity.

Continuous cultivation of the annual crops led to a decrease in the amount of organic carbon stored in the soil as compared to the perennial crops. In horticultural systems, because the economic parts of the plants are harvested, only a small percentage of the production becomes available for incorporation into soil to enhance the organic carbon pool. All the aboveground production may be harvested, leaving only the root biomass. The low SOC recorded under the annual crops could be attributed to the little organic inputs from its component crops.

3.4 Carbon dioxide sequestration under different land use systems

Carbon dioxide sequestration at different depths as influenced by different horticulture crops is presented in Table 2.

Horticulture land use system	4 year old cultivation			
	CO_2 sequestration (Mg ha^{-1})			
	0-15 cm	15-30 cm	30-50 cm	50-100 cm
Mango orchard	5045.33	4995.60	6647.25	16434.95
Cashew orchard	4565.84	4569.22	6163.76	14957.08
Rose block	3691.10	3683.28	4792.65	11800.95
Vegetable block	3633.30	3572.19	4801.82	11413.95
Medicinal and aromatic block	3574.39	3502.06	4642.55	11312.04
SEm ±	228.45	227.45	300.04	733.45
CD at 5%	684.45	677.45	900.12	2194.45

The carbon dioxide sequestration was differed at different depth. The highest sequestrated carbon dioxide was observed in the subsurface layer *i.e.,* 50-100 cm and lowest was observed in 0-15 cm, 15-30 cm and 30-50 cm soil depths. The carbon dioxide sequestration was increased with increase in soil depths. Among different cropping systems, the mango orchard had maximum carbon dioxide sequestration (16434.95Mg ha^{-1}) which is on par with the cashew orchard (14957.08Mg ha^{-1}) and lowest was observed under the medicinal and aromatic block (11312.04Mg ha^{-1}).

The CO_2 sequestration is less under the annual cropping systems as compared to the perennial crops. This is due to the land use changes and soil degradation processes as well as the rapid decomposition of organic matter in cultivated soils were the major cause for the release of CO_2 from the systems, as the land use systems that added more residues recorded the less emissions of CO_2. Cultivation of annual crops reduces the carbon pools and increase CO_2 emissions.

4. Conclusions

The study showed that the land use systems that sequestered more carbon and less CO_2 emission was ranked as: mango > cashew > rose > vegetable > medicinal and aromatic plants. The land use systems *i.e.,* perennial horticulture crops like mango and cashew orchard that added more residues recorded less emission of CO_2 and finally, it was observed that perennial crops increase the SOC content than annual crops. Soil C sequestration is a multiple purpose strategy, it restores degraded soils, enhances the land productivity, improves the diversity, protects the environment and reduces the enrichment of atmospheric CO_2 and mitigates climate change.

5. References

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