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Carbon Sequestration Potential of different Land Use Pattern in Calcareous Soils of Muzaffarpur District, Bihar

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ABSTRACT: Among the land use pattern, forest soils are an important component of the global C cycle and it store large amounts of organic carbon (OC). Comparing the carbon storage in various land use systems, required to assess organic carbon in the soils. In order to that, the study was conducted on the estimation of soil C stocks in three important land use systems viz. Mango orchards, cultivated and fallow lands in the Muzaffarpur district of Bihar. For the assessment of various soil properties, the soil samples were collected from three soil depth (0-15, 15-30 & 30-45cm) using soil core cutters. Among the different age of mango tree, the increased value of organic carbon obtained in 25 years old mango orchard than 10 and 20 years old trees respectively. The soil pH differed across the land use system, where, higher value was recorded in fallow land followed by cultivated land. However, lower pH was recorded in soils of mango orchard than other land use system may be due to addition of litter leaves of mango orchard. The higher concentrations of all micronutrients were recorded higher in surface soil. The information made by study the effects of different land use types on soil organic carbon stock is crucial for best land management practices and combating climate change and enhancing ecological restoration.

Keywords: soil organic carbon, micronutrients, orchard.

INTRODUCTION

The human activities are changing the rate of natural exchange of carbon between the atmosphere and the terrestrial biosphere through use of various pattern of land use, land use change and forestry activities. Land use change influences ecosystem processes that affect CO_2 fluxes between the atmosphere and ecosystems (Franzluebbers, 2005). Agro-forestry ecosystem stored an estimated available C ranged from 0.29 to 15.21 Mg C ha^{-1} $year^{-1}$ above ground, and 30-300 Mg C ha^{-1} $year^{-1}$ up to 1 m depth in soil (Nair *et al*., 2010). Land management practices, which sequester carbon or reduce the emissions of CO_2, is being considered in the mitigation strategies of climate change (Zomer *et al*., 2008; Logah *et al*., 2020). Among the land use pattern, forest soils are an important component of the global C cycle as they store large amounts of organic carbon (OC). Particularly in mountain forest ecosystems, soil organic matter is of crucial importance for site productivity and ecosystem services, but probably sensitive to climate change. Soil carbon is important as it determines ecosystem functions, influencing soil fertility, water holding capacity and other soil parameters. It also plays a significant role in the mitigation of atmospheric levels of greenhouse gases with special reference to the CO_2. The maintaining of soil fertility and crop productivity in a sustainable manner which is possible through an appropriate combination of organics, inorganics and bio-fertilizers in an integrated manner to harness their complementary advantage (Vinayalakshmi *et al.,* 2022).

The soil represents the most important long-term organic carbon reservoir in the terrestrial ecosystems, which act as a source or a sink of atmospheric CO_2. It contains approximately twice (1500 Pg C) the amount of carbon (C) in the atmosphere (about 800 Pg C) and about three times the amount in plant biomass (500 Pg C) (Lal 2004; Intergovernmental Panel on Climate Change (IPCC) 2007; Tarnocai 2009). Land-use types have major influence on soil C stock. The type of vegetation cover influences the abundance of organic carbon in the soil (Jobbagy and Jackson 2000), which in turn affects plant production.

Soil organic carbon also promotes soil quality in terms of chemical, physical, and biological soil properties, and its reduce content in soil widely affecting the soil quality. In north Bihar particularly Muzaffarpur, East Champaran and Samastipur have immense potentiality for cultivation of mango and litchi crop, added good amount of soil organic matter. The amount of carbon that gets sequestered in biomass and soil is dynamic as it depends on land use change (Shrestha and Singh

2007), types of species with different management regimes and soil profile.

The soils quality and imbalance nutrients availability affecting the potential yields of fruits crops. The cultivation of fruit crops is adversely affected by the deficient quantity of major and micronutrients in the soils at different growth stages, particularly at flowering and fruiting stages and that may cause considerable losses in terms of quality and quantity. Crop diversification shall not only improve the productivity and income but also maintains the carbon stock and soil quality and the environmental sustainability (Kumari *et al*., 2022). The organic content in horticulture crops is important inputs which act to maintain soil physical conditions and moisture retention capacity of soils. Precise and comprehensive measurements of soil health will provide the basis for soil health management (Liu *et al.,* 2018). Fruit trees, in particular, represent a significant portion of land use in several regions and have the potential to act as a net CO_2 sink, storing C in the permanent woody structure of the tree (Scandellari *et al.*, 2016) and in the soil, especially when soil management includes the presence of a grass cover (Chamizo *et al.*, 2017; Tezza *et al.*, 2019). Despite the fact that the data obtained from various study will help to predict the rate of change of carbon stock and other environmental variables associated with land-use systems and also engender a better understanding of the influence of terrestrial ecosystems on the climate. This study therefore, taken to know the how much deposition of organic carbon and fertility status in different land use system in calcareous nature of soils.

MATERIALS AND METHODS

The study was conducted on the estimation of soil C stocks in four important land use systems viz. Mango orchards, cultivated and fallow lands in the Muzaffarpur district of Bihar. The study area is situated on the southern bank of the river *Burhi Gandak* at an elevation of 52.18 meter above mean sea level and intersected by 25.98°N latitude and 85.60°E longitude. It consisting semi- arid, sub–tropical climate with hot dry summer, moderate rainfall and cool winter. Soils are well, drained calcareous in nature, alkaline in reaction which developed on the sediments of the river *Burhi Gandak* mainly by the deposition of the sediment through the ages.

For the assessment of various soil properties, the soil samples were collected from three soil depth (0-15, 15-30 & 30-45cm) from the different three types of land use systems using soil core cutters. For the study of carbon sequestration, the orchards were earmarked on different age *viz.* 10, 20 and 25 years old respectively. In each land use type, three 8 m × 8 m transects were identified for soil sampling. From each transect, five random soil samples were collected and composite samples were obtained by mixing of five samples. The sampling was performed depth wise, the composite soil samples in the mango and litchi orchards were collected between rows that were approximately 1 m away from the base of the mango and litchi trees. The soil samples were processes in the laboratory and used for determination of physico-chemical properties. The pH of soil was determined using Potentiometric method and total soluble salts by electrical conductivity meter. $CaCO_3$ content (%) was estimated by rapid titration method (Piper 1950). The soil organic carbon content (g kg^{-1}) were analysed using Walkley and Black (1934). The available N, P, K & S in soils were analysed for available N (Subbiah and Asija 1956), 0.5 M $NaHCO_3$ (pH 8.5) extractable P (Olsen,, 1954), 1N NH_4O Acetate extractable K by flame photometer and 0.15 % $CaCl_2$ extractable sulphur (Cheshin and Yien 1951). The micronutrient content was determined by using method (Lindsay and Norvell 1978). The following formulae were used to calculate the soil carbon stock (t ha^{-1}).

Soil Organic Carbon (%) × Bulk density (Mg m^{-3}) × depth (cm).

RESULTS AND DISCUSSION

Soil organic carbon content (mg kg^{-1}) of land use systems examined is represented in Fig. 1. Generally soil organic carbon decreased with the depth in all the land use system. However, comparatively organic carbon content recorded higher in mango orchard than other land use system *viz*., cultivated and fallow land showed in Fig. 1. Considering the different age of mango tree, the increased value of organic carbon recorded with 25 years old mango orchard than 10 and 20 years old respectively. Similarly, soil carbon stock and equivalent CO_2 across the land use systems, lower value were recorded in cultivated land followed by other land use systems depicted in Fig. 1. The higher total carbon in mango orchard may be attributed to the different quantities and qualities of organic matter input through fresh litterfall, living organisms and root activity (Vesterdal *et al*., 2008). Perennial vegetation is more efficient as compared to annual vegetation as it assigns a greater proportion of C to below ground and often extends the growing season (Morgan *et al*., 2010).

Mango agro-ecosystems sequester substantial amounts of carbon in addition to providing economic gains, although they make little contributions to improving soil nutrients (Tom-Dery *et al.,* 2015). The lowest soil organic carbon recorded for soil of cultivated land might be due to the low input of organic matter to the soil and high rates of oxidation of soil organic matter due to tillage (Dereje *et al.,* 2020). Ganeshamurthy *et al*. (2020) reported that in the same plots, the conservation practices have improved the soil physical, chemical, biological, and biochemical health, and thereby, the tree health with CHP has improved over time. The maximum total active carbon pool was 36.2 Mg C ha^{-1} in mango orchard found in 1.2 times higher than control (Naik *et al.,* 2016).

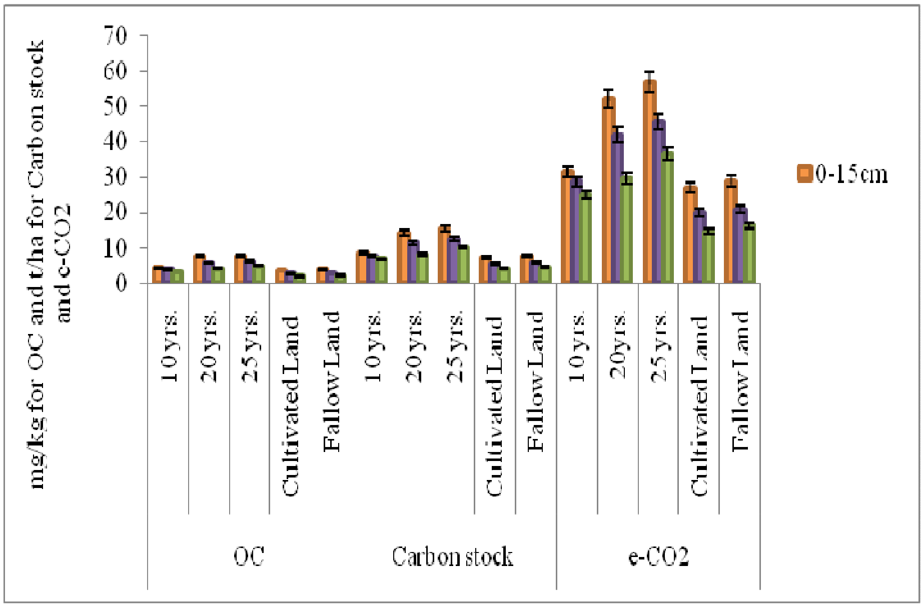

Fig. 1. Mean value of soil organic carbon content (mg kg^{-1}), carbon stock and e-CO_2 in different land use system at various sampling depth.

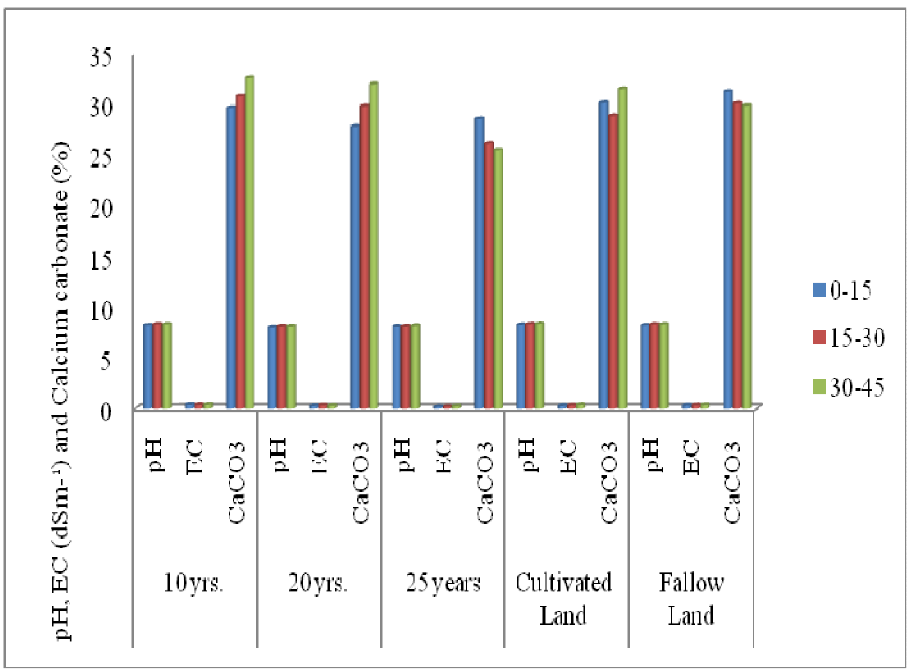

Fig. 2. Mean value of soil pH, EC (dSm^{-1}) & $CaCO_3$ (%) in different land use system at various sampling depth.

The soil pH differed across the land use system, where, higher value was recorded in fallow land followed by cultivated land. However, lower pH was recorded in soils of mango orchard than other land use system reveals in Fig. 2. The lower pH was observed due to addition of litter leaves of mango orchard. However, in respect of total soluble salt, very little variation was observed in all land use system showed in Fig. 2. The result showed that the calcium carbonate (%) was observed increased with depth of soil in 10 and 20 years old orchards. However, it was recorded decreased with the depth of soil. The increased pH with increasing depth of soil profiles was ascribed to the deposition of exchangeable bases at lower depth of soil profiles resulting from heavy rainfall in the region during the rainy season (Balpande *et al.,* 2007). Similar trend was also showed in cultivated and fallow land. Among the age levels of the orchard irrespective of health condition, the pH of the 6–7-year-old (A3) orchard was significantly better than the 1–3-year-old orchard and was at par with the 4–5-year-old orchard (Naik *et al.,* 2015).

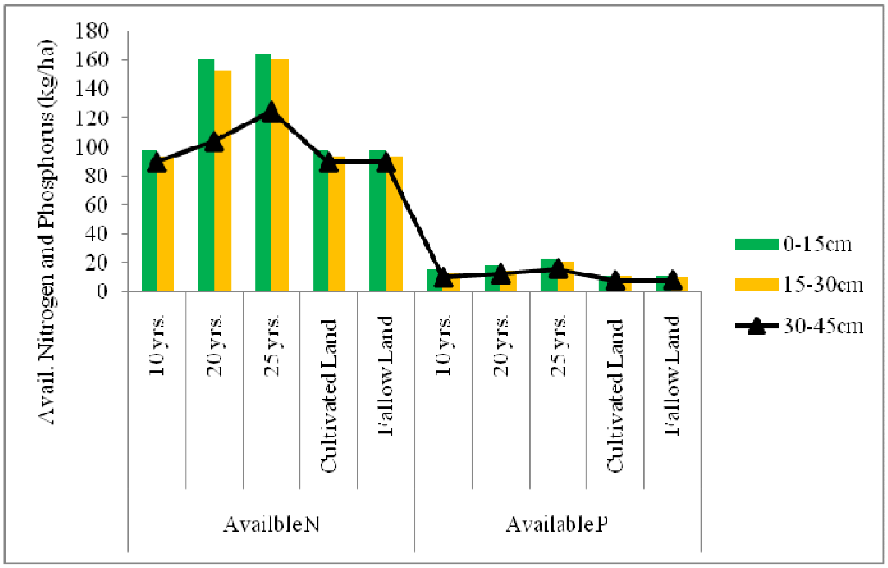

Fig. 3 Mean value of available Nitrogen and Phosphorus (kg ha^{-1}) in different land use system at various sampling depth.

The variability in amount of soil available nitrogen and phosphorus stored in various land use system showed with soil depth showed in Fig 3. Higher available nitrogen and phosphorus was recorded in upper soil layer than lower. Musvoto *et al*. (2000), while studying decomposing and releasing of nutrients through the mango tree litter during 18 months, found that there is N immobilization by that material.

The variability in available potassium and sulphur recorded higher in soils of mango orchard might be due to addition of leaf litters, however, other land use systems, like cultivated and follow land recorded comparatively low sulphur and potassium in soils. Among the age of tree, it was found that the nutrient content recorded more in 20 years old tree than 25 and 10 years. Similarly, potassium and sulphur content observed reduced in quality with depth is showed in Fig. 4.

Fig. 5 and 6 depicting comparative study among the availability of micronutrients in different land use system with soil depth calcareous soil. The higher concentrations of all micronutrients were recorded higher in surface soil. However, it was found gradually lower concentration with the soil depth. Similarly, the age of trees also affected the quantity of nutrients because of content soil organic matter. The similar results were also reported with respect to content of micronutrients reported by Joshi *et al.* (2015).

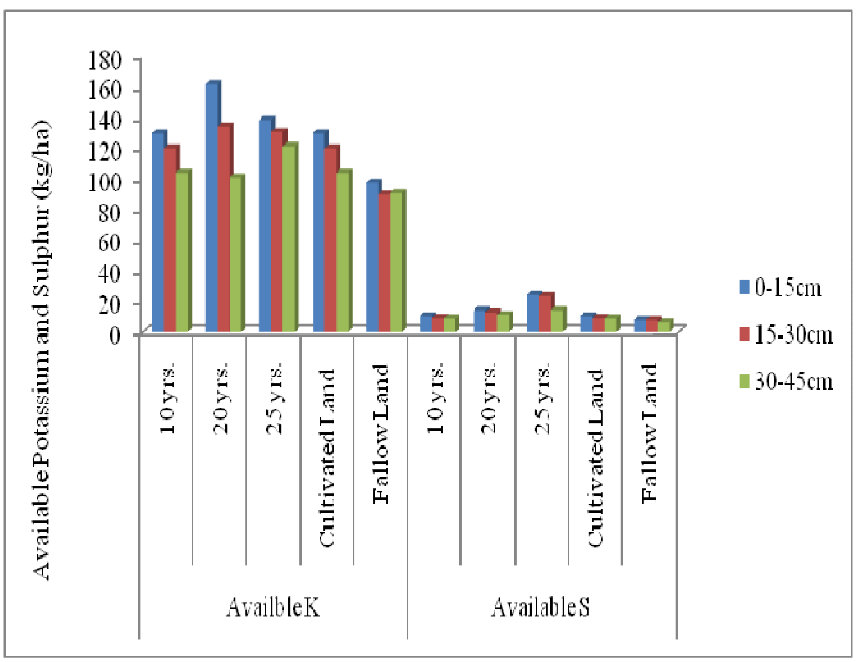

Fig. 4. Mean value of available Potassium and Sulphur (kg ha^{-1}) in different land use system at various sampling depth.

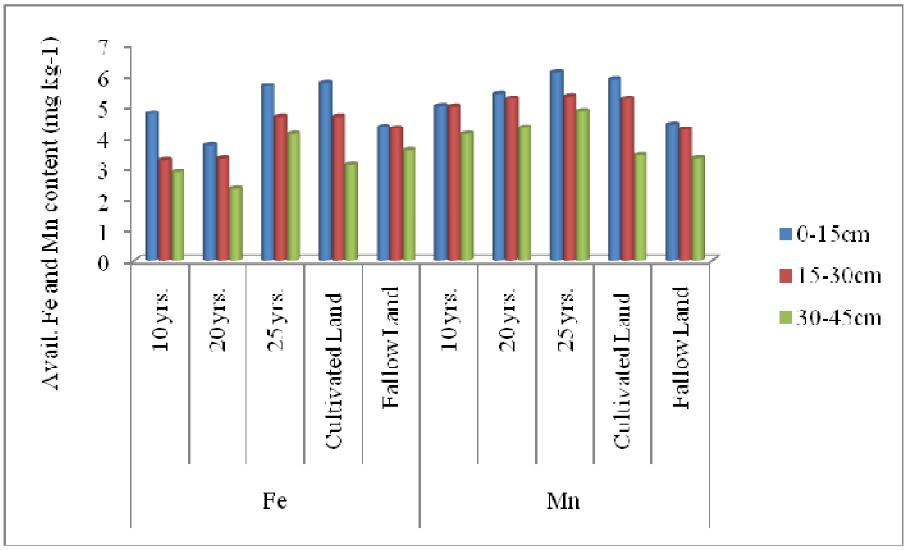

Fig. 5. Mean value available iron and manganese (mg kg^{-1}) in different land use system at various sampling depth.

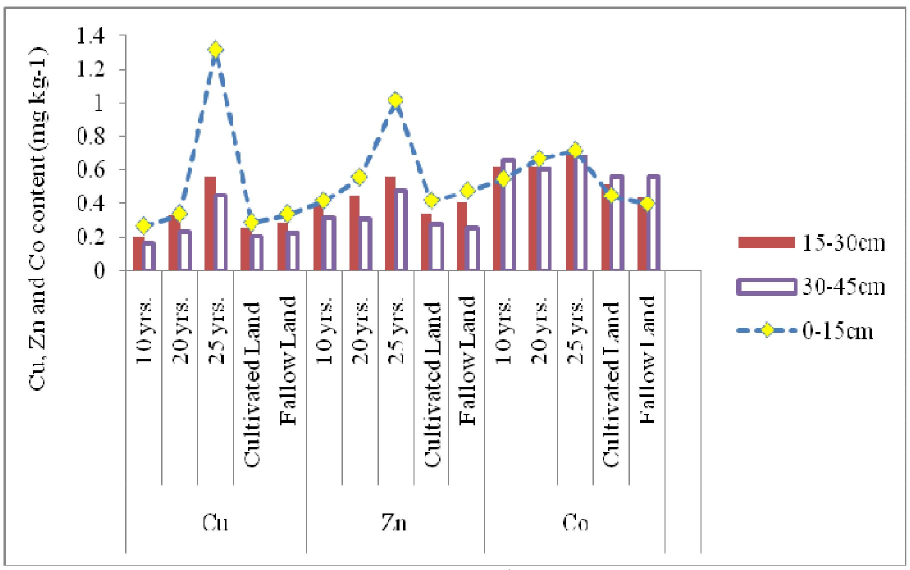

Fig. 6. Mean value available copper, zinc and cobalt (mg kg^{-1}) in different land use system at various sampling depth.

CONCLUSIONS

The present study has shown that the carbon (C) sequestration can be enhanced by shifting the land use toward perennial systems. Among the land use pattern, organic matter deposition was found more in mango orchard soils than other land use system. However, among the tree age, the increased content of organic carbon value obtained with 25 years old tree orchard than 10 and 20 years old trees respectively. The higher content of macro and micronutrients was recorded in upper soil layer than lower.

FUTURE SCOPE

The orchards of mango may be a good source of built-up and possibility of storing carbon stock in soils than other land use pattern. It may also become a large input of organic matter into the soil which enhanced the fertility potential of soils.

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Conflicts of Interest. None.

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