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International Journal of Recent Scientific Research
Vol. 3, Issue, 9, pp.771 -774, September, 2012

International Journal of Recent Scientific Research

ISSN: 0976-3031

ENHANCEMENT OF SOIL ORGANIC CARBON (SOC) IN AGRICULTURAL LANDS WITH FORAGE CROPS CULTIVATION IN THENKASI, TIRUNELVELI DISTRICT, TAMILNADU, INDIA

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ARTICLE INFO

Article History:

Received 10th August, 2012
Received in revised form 20th August, 2012
Accepted 29th August, 2012
Published online 12th September, 2012

Key words:

Fodder maize; Fodder cowpea; hybrid Napier; hedge lucerne; Soil Carbon sequestration; climate change

ABSTRACT

Agricultural systems have the potential to sequester carbon from the atmosphere and alleviate climatic change. Sequestration of atmospheric carbon is one of the mitigation measures for encountering the anthropogenic climate change due to emission of green house gases. Based on the field experiment and analysis, it is shown that Hedge Lucerne, an economically viable crop, also provides an efficient carbon sequestration system. A comparison of normalized carbon sequestered by different crops with that by Hedge Lucerne shows it to be more efficient. Similarly, the carbon sequestered is found to be the highest by Hedge Lucerne in comparison to three other crops viz. Hybrid Napier, Fodder cowpea and Fodder maize. Analysis of cropping systems was conducted to determine potential net carbon sequestration in agricultural systems. Carbon sequestration rates calculated from the analysis was used to determine potential carbon storage in Thenkasi (Tirunelveli district, Tamilnadu, India). Rates of carbon sequestration based on crop management practices are expected to provide an accurate basis for carbon sequestration initiatives.

INTRODUCTION

Greenhouse gases (GHG) emissions beyond the limits in the atmosphere and the consequential climatic change will have major effects in the near future (IPCC, 2001). Current circumstances are still burdened with uncertainty, serious deleterious effects are expected though some positive effects are also expected and it is essential that a number of actions be undertaken in order to reduce carbon dioxide concentrations and to increase their sequestration in soils and biomass. In the present day context of climate change and global warming India has the potential of turning in to the core strength of Indian economy, for a strong foundation for sustainable development (Anand, 2007), which heavily depends on export of material of biological origin, products from agricultural and forestry, fisheries, products of animal husbandry, carbon sequestration, bio-prospecting, ecotourism, bio-fuel and natural beverages (CBDA, 2002).

The amount of carbon stored in Soil organic matter (SOM) is influenced by the addition of carbon from dead plant material and carbon losses from respiration, the decomposition process and both natural and human disturbance of the soil. Soil organic matter (SOM) has a very complex nature and is generally associated with the mineral soil constituents especially with soil organic carbon. The development of agriculture has involved a large loss of soil organic matter (Ryan and Spencer, 2001). Different land management practices can be used to increase soil organic matter content, such as increasing productivity and biomass. The main ways to achieve an increase in organic matter in the soil are through conservation agriculture, involving minimum or zero tillage and a largely continuous protective cover of living or dead vegetal material on the soil surface. No-till practices sequester a larger amount of carbon than other tillage intensities, and may sequester a larger amount of carbon depending on crop type (Drechsel *et al.*, 2004). Farming practices that involve minimal disturbance of the soil and encourage carbon sequestration, farmers may be able to slow or even reverse the loss of carbon from their fields (EPA, 2008).

Recent studies have highlighted the substantial contribution of agriculture to climate change mitigation and adaptation (Niggli *et al.*, 2009; Scialabba and Muller, 2010). The potential of agriculture to mitigate climate change is mostly claimed on the basis of assumptions concerning the soil carbon sequestration potential of organic management. Terrestrial carbon sequestration is proposed by scientists as an effective mitigation option because it combines mitigation with positive effects on environmental conservation and soil fertility (Smith *et al.,* 2008). Carbon sequestration in biomass and soil has been proposed to be a key strategy to reduce atmospheric CO_2; these sequestration strategies are likely to play a major role in the next 20-30 years. Adoption of improved agricultural practices have great potential to increase the amount of carbon sequestered in soils by enhancing the amount of SOC and to mitigate carbon dioxide emission

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effects on climate change, since soil organic carbon plays an important role in the soil's biological, chemical and physical properties (Thirtle *et al.*, 2002). Few studies have been performed on the distribution of carbon, however, in the present study the potential of fodder cowpea, fodder maize, hybrid Napier and Hedge lucerne in carbon sequestration through agriculture was estimated in Thenkasi (Tirunelveli district, Tamilnadu, India).

MATERIALS AND METHODS

The field study was conducted during 2010-11 at Thenkasi, (Tirunelveli district, Tamilnadu, India). The study area is located at an altitude of 183m, 09° 00.847ˈ N and 77° 17.389ˈE. The soil texture analysis had sand (2-0.05 mm) 50-62 %, silt (0.05-0.002 mm) 7-20 % and clay (<0.002 mm) 8-33 % respectively. The field site was divided into 4 blocks (10 x 10 m) with 3 replicates in each block as a randomized complete block design. Field plots measuring 1200 m^2 were used for the four crops. Standard agronomic practices including farm yard manure and fertilizers were followed in cultivation of these crops (CPG, 2005). Crops were harvested at random periodically up to 240 days to study biomass accumulation pattern and for carbon analysis. Fodder crops of hedge lucerne and Hybrid Napier were of perennial group and fodder maize and fodder cowpea were annual crops. Finally, the crops were harvested as: one harvest of fodder maize (50 days); fodder cowpea (55 days); hedge lucerne (60 days) and hybrid Napier (first cut at 90 days and 60 days consecutively for second cutting) along with roots.

The soil samples were collected from the depth of 30cm. Soil samples were dried in oven (at 80°C) to constant weight to derive dry matter production. The dried samples were ground to pass through 0.2 mm mesh and were analyzed for carbon content using Analytikjena multi N/C 2100S carbon analyzer. The total carbon present before cultivation of crops and amount of carbon captured at the time of harvest was estimated. Soil Bulk Density (Mg/m^3) was calculated by dividing the dry weight of the soil with the volume of the soil. Tonnes carbon per hectare was calculated by the following formulae:

Tonnes carbon per ha = SOC (%) x Soil Bulk Density (Mg/m^3) x Soil Sampling Depth (cm) One-way ANOVA (multiple comparison tests) was performed to analyze significant difference in rate of carbon sequestered.

RESULTS AND DISCUSSION

Legume-based crop rotations and the use of compost and manure are preferred as viable alternatives to the rice-wheat system in south Asia for increased productivity, and improvements in the SOC pool and soil quality (Pal, 2003; Dwivedi *et al*., 2003). The soil organic carbon estimated before the onset of cultivation ranged from 0.42 to 0.50 %. At the time of harvest the estimated soil organic carbon was 0.83, 0.81, 0.91 and 1.01 for fodder maize, fodder cowpea, hybrid Napier and hedge lucerne respectively (Figure 1). It was found that hedge lucerne sequestered carbon higher than hybrid Napier, fodder cowpea and fodder maize (Figure 2). The rate of carbon sequestered with forage crops were 53.04, 52.08, 57.83 and 64.86 tonnes per ha, respectively. The calculated total carbon present before cultivation was 30.67 tonnes of carbon per ha (Figure 3). The calculated soil bulk density showed positive correlation with the soil organic carbon sequestered by the forage crops in Thenkasi (Figure 4). Sustainable management of soil resources, through no-till farming, retention of crop residue as mulch and use of manure and compost to enhance soil fertility is an integral component related to improving agricultural productivity and mitigating climate change. To preserve SOC, the conservation tillage practices like no tillage, zero tillage and ridge tillage has been gaining popularity under conservation tillage. By minimizing soil tillage, atmospheric increase of CO_2 can be reduced while at the same time increasing the soil carbon accumulation (sequestration) and soil quality.

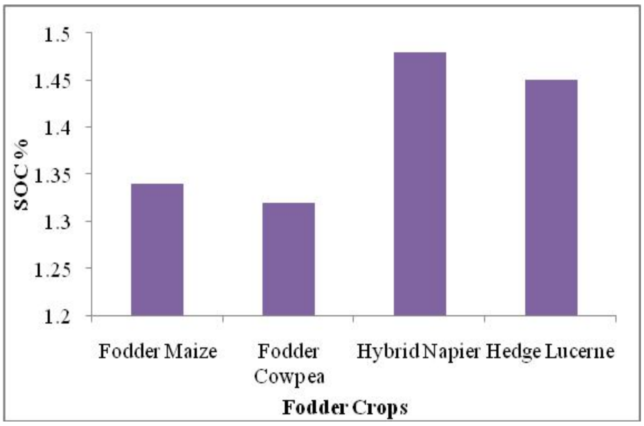

Figure 1 Variation of soil organic carbon accumulated by fodder crops

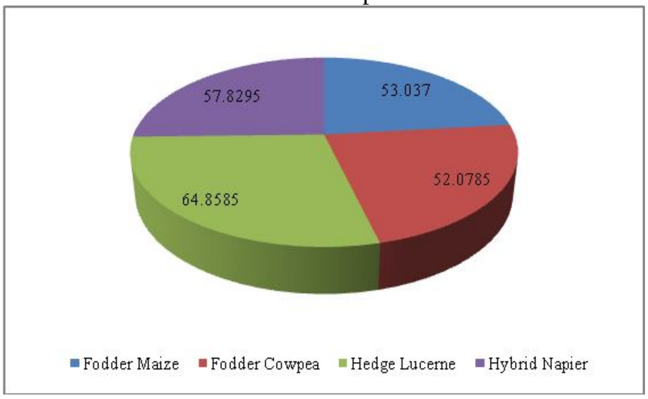

Figure 2 Soil carbon sequestered by the fodder crops

Similar to rotation impacts, organic amendments and irrigation can increase SOC storage by enhancing plant production and subsequent C input to the soil. Productivity of individual crops influences SOC storage due to differences in the amount of crop residue that is left in the agricultural field and incorporated into soil organic matter. Tillage management had a more variable impact on SOC storage than long-term cultivation in terms of both increase and decrease in storage with the implementation of reduced and no-till practices, according to the field experiments. Variation in rotation practice and the use of organic amendments affected SOC storage but the impacts were mostly smaller than those estimated for tillage. Changing tillage and cropping practices also altered SOC storage, and the trends in temperate versus tropical regions were similar to the patterns for long-term cultivation. Increasing carbon sequestration in agricultural soils and making soil a net sink for atmospheric carbon can be achieved by adoption of the best management practices, application of fertilizers, crop rotation, and improved residue management (Lal 2003).

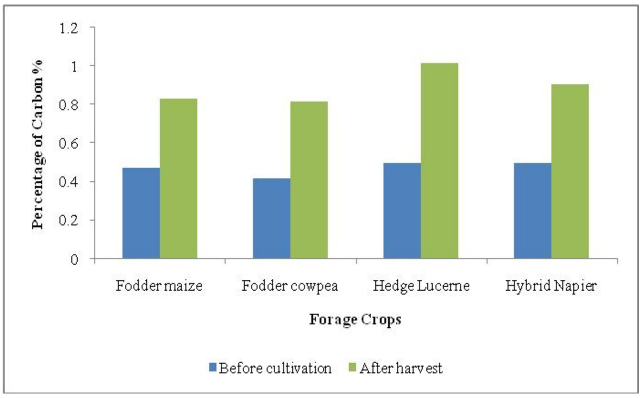

Figure 3 Comparison between the total carbon present before cultivation and after the cultivation of forage crops in the soil

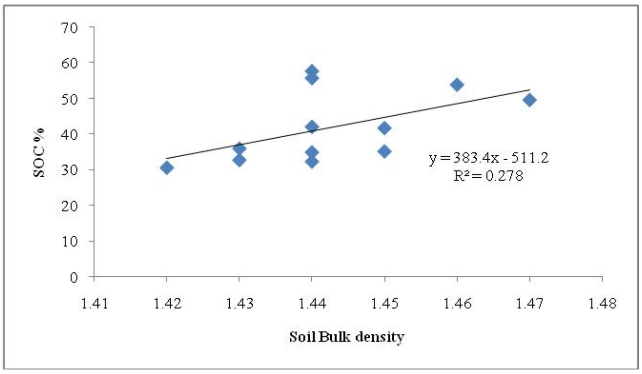

Figure 4 Correlation between the bulk density (Mg/m^3) and Soil organic carbon (%) sequestered by the fodder crops

Among these practices, the benefits of balanced application of mineral fertilizers and manures in maintaining and increasing levels of SOC in agricultural soils have been well documented (Rudrappa et al. 2006). Many long-term fertilizer experiments worldwide have proved that balanced fertilization using mineral fertilizers with organic manures can improve the nutrient status of the soil and maintain high crop yields and high levels of residues that can be returned to the soil to increase the SOC concentration (Holeplass *et al.*, 2004).

In an experiment in north China, Meng et al. (2005) reported that balanced application of NPK fertilizers and organic manure significantly increased SOC accumulation, to averages of 0.1 Mg ha^{-1} and 1.01 Mg ha^{-1}, respectively. Jiang et al. (2006) reported that continuous application of FYM and NPK mineral fertilizers increased SOM by 80 and 10% in south China. FYM was more effective than inorganic fertilizers at increasing the SOC stock. Whalen et al. (2003) found that application of composted manure for 2 years increased SOM up to 45 Mg ha^{-1} year^{-1} in conventional and no-tillage systems. Yang et al. (2003) who reported that NPK fertilization were inadequate for maintaining SOC levels under conditions of conventional management associated with no crop residues returning to the soil. Increased crop yields and residue returns with long-term inorganic fertilizer application can result in a higher SOC content than when no fertilizers are applied. This suggested that application of manure has strong effect on SOC maintenance and accumulation in cropping systems; this is consistent with results obtained from long-term experiments elsewhere (Rudrappa *et al.*, 2006). Lal (2003) reported application of inorganic fertilizer is important to obtaining high yields, but may have little impact on SOC concentration unless used in conjunction with no-till and residue management. In the current study conventional tillage practice was performed, and the aboveground biomass of wheat and maize and the roots of maize were removed. The level of organic carbon in soil is believed to be a function of the net input of organic residues by the cropping system (Gregorich *et al.*, 1996). Soil and crop-management practices such as crop rotation, residue management, and fertilization therefore have a substantial effect on the level of SOC over time. Agronomic production must also be increased, for which improvement of the SOC pool is an important determinant.

CONCLUSIONS

There is increasing urgency for a stronger focus on adapting agriculture to future climate change. There are many potential adaptation options available at the management level, often variations of existing climate risk management. However, there are as yet relatively few studies that assess both the likely effectiveness and adoption rates of possible response strategies. Agricultural lands can potentially sequester C and mitigate greenhouse gas emissions through adoption of reduced and no-till management, use of high C input rotations that include hay, legumes, pasture, cover crops, irrigation or organic amendments, setting aside lands from cropland production, and through cropping intensification. Moreover, implementation of these practices will generally sequester more C in agricultural soils.

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