DISTRIBUTION OF SOIL ORGANIC CARBON (SOC) IN AGRICULTURAL LANDS BY FARMING FORAGE CROPS FOR MITIGATING CLIMATE CHANGE

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Abstract
Agro ecosystems have the potential to sequester atmospheric carbon and alleviate climatic change. The present study was conducted to quantify the impact of changing soil organic carbon (SOC) storage with farming forage crops. Four types of forage crops; fodder maize and fodder cowpea of annual, Hedge Lucerne and Hybrid Napier of perennial were cultivated in Kondaiyampalayam (Erode district, Tamilnadu, India). Based on the field experiment and analysis, Hybrid Napier, an economically viable crop, also provides an efficient carbon sequestration system. A comparison of normalized carbon sequestered by different crops with that by Hybrid Napier shows it to be more efficient. Similarly, the carbon sequestered is found to be the highest by Hybrid Napier in comparison to three other crops viz. Hedge Lucerne, 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 Kondaiyampalayam (Erode district, Tamilnadu, India). From the present study Hybrid Napier stands to be a potential fodder for carbon sequestration in agricultural ecosystems. Rates of carbon sequestration based on crop management practices are expected to provide an accurate basis for carbon sequestration initiatives.

INTRODUCTION
Agriculture has a dramatic capacity to sequester carbon dioxide and worldwide, farmers have the opportunity to offset their own emissions and those of other industries. Soils and plants contain 2.7 times more carbon than the atmosphere; they represent the earth’s largest store of biological carbon other than ocean. Contribution towards environmental sustainability depends upon the different methods focused in the storing of soil carbon in soil sinks. Improved soil’s agronomic capabilities increases the organic matter content of soil, which in return produces better soil and better crops, improves water conservation and reduces erosion [1]. Carbon dioxide and other greenhouse gases (GHG) emissions beyond the limits in the atmosphere and the consequential climatic change will have major effects in the near future [2]. 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 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 [3]. Climate change causes other global concerns such as loss of biodiversity, changes in land use and soil degradation. It may also lead to limiting the capacity to sequester carbon [4]. India is a large country with 15 agro-climatic zones, with diverse seasons, crops and farming systems. For a majority of people in India, agriculture is the main source of livelihood. Since 1950s agricultural productivity has witnessed a brisk growth owing to novel crop varieties, fertilizer use and development in irrigated agriculture. Agriculture plays a major role in economic development and reducing poverty [5]. Agriculture is the most vulnerable sector to climate change and will leave its impacts on Indian agriculture in various direct and indirect ways. This obviously means an impact on the lives and
Terrestrial carbon sequestration is proposed by scientists as a key strategy to reduce atmospheric carbon dioxide (CO$_2$); these sequestration strategies are likely to play a major role in the next 20-30 years. Adoptions of improved agricultural practices have great potential to increase the amount carbon sequestered in soils by enhancing the amount of soil organic carbon and to mitigate carbon dioxide emission and effects on climate change [6]. Soil organic matter (SOM) has a very complex nature and is generally associated with the mineral soil constituents especially with organic carbon in soil. The development of agriculture has involved a large loss of soil organic matter [7]. 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. 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 [8].

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. The calculated soil bulk density (Mg/m$^3$) was 43.45 tonnes of carbon per ha (Figure 3). The estimated soil organic carbon was 0.91, 1.09, 1.43 and 1.13% for fodder maize, fodder cowpea, hybrid Napier and Hedge Lucerne respectively (1.13% for fodder maize, fodder cowpea, hybrid Napier and Hedge Lucerne respectively). Carbon sequestration in biomass and soil has been proposed to be a major role in the next 20-30 years. Adoptions of improved agricultural practices have great potential to increase the amount of carbon sequestered in soils by enhancing the amount of soil organic carbon (SOC). Few studies have been performed on the distribution of carbon, however, in the present study the ability of fodder cowpea, fodder maize, hybrid Napier and Hedge Lucerne in carbon sequestration was estimated before the onset of annual crops.

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**RESULTS AND DISCUSSION**

The soil organic carbon (%) estimated before the onset of farming ranged from 0.61 to 0.68 %. At the time of harvest the estimated soil organic carbon was 0.91, 1.09, 1.43 and 1.13% for fodder maize, fodder cowpea, hybrid Napier and Hedge Lucerne respectively (Figure 1). It was found that Hybrid Napier sequestered carbon higher than Hedge Lucerne, fodder cowpea and fodder maize (Figure 2). The rate of carbon sequestered with forage crops were 58.15, 69.65, 72.21 and 91.38 tonnes per hectare (ha), respectively. The calculated total carbon present before cultivation was 43.45 tonnes of carbon per ha (Figure 3). The calculated soil bulk density (Mg/m$^3$) showed positive correlation with the soil organic carbon sequestered by the forage crops in Thenkasi (Figure 4). 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 [13].

**MATERIALS AND METHODS**

The field study was conducted at Kondaiyampalayam (Erode district, Tamilnadu, India) (11°32 52.81’ N and 77°32 55.30’ E) during 2010-11. The farm 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 [12]. 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 (Furnace Temperature: 950°C, NDIR detector and oxygen as supportive gas). 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 hectare (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 the rate of carbon sequestered.

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**Figure 1.** Variation of soil organic carbon accumulated by fodder crops

Livelihoods of millions of Indians. It also plays a significant role in reducing carbon dioxide and other greenhouse gases. Adoptions of improved agricultural practices have great potential to increase the amount of carbon sequestered in soils by enhancing the amount of soil organic carbon and to mitigate carbon dioxide emission and effects on climate change [6]. Soil organic matter (SOM) has a very complex nature and is generally associated with the mineral soil constituents especially with organic carbon in soil. The development of agriculture has involved a large loss of soil organic matter [7]. 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. 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 [8].

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 [9]. Recent studies have highlighted the substantial contribution of agriculture to climate change mitigation and adaptation [10, 11]. Carbon sequestration in biomass and soil has been proposed to be a key strategy to reduce atmospheric carbon dioxide (CO$_2$); these sequestration strategies are likely to play a major role in the next 20-30 years. Adoptions of improved agricultural practices have great potential to increase the amount of carbon sequestered in soils by enhancing the amount of soil organic carbon (SOC). Few studies have been performed on the distribution of carbon, however, in the present study the ability of fodder cowpea, fodder maize, hybrid Napier and Hedge Lucerne in carbon sequestration through farming in agricultural lands were estimated in Kondaiyampalayam (Erode district, Tamilnadu, India).
According to Ravindranath [14] the standing biomass in India is estimated to be 8,375 million tons for the year 1986, of which the carbon storage would be 4,178 million tones. Increasing soil organic carbon in any situation is essential to generate and maintain healthy soils [15]. Carbon sequestration in agricultural lands will benefit the farm economy of those farmers who sequester the carbon, and anyone can participate without a regional bias. Sustainable management of soil resources, through no-till farming, retention of crop residue as manure and compost to enhance soil fertility is an integral component related to improving agricultural productivity and mitigating climate change. Evidence on long-term experiments reveals that soil carbon (C) losses as a result of oxidation and erosion can be reversed through improved soil management such as reduced tillage [16]. Therefore, improved land-management practices to enhance C in soils have been suggested as a viable way to reduce atmospheric C content significantly [17]. Evidence suggests that certain fractions of SOC are likely to respond more rapidly than total soil C to land use change and management. It has been shown that C presented in particulate organic matter (POM) can accumulate rapidly under land management systems that minimize soil disturbance and may also provide an early indicator of changes in total soil C under different land use and management practices [18]. Significant differences in SOC between land-use treatments indicate that soil C can increase by converting annual crops to perennial forages. Studies have suggested that land use can have a wide range of effects on soil C but will be influenced by climate, soil texture, nutrient status, and the time periods [19]. The differences in soil C between land use treatments divided by duration of land use conversion can serve as an indicator of C sequestration rate [20]. Agricultural lands can 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.

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 [21]. 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 [22]. The set of practices identified in this study assume that the objective of farmers is to increase both carbon sequestration and income. However, farmers’ practices can be flexible in order to minimize risk by showing opportunistic responses to the changing environmental conditions [9]. Soil carbon sinks resulting from sequestration activities are not permanent and will continue as long as appropriate management practices are maintained. In any case land management or land use is reversed, the carbon accumulated will be lost, usually more rapidly than it was accumulated. Soils are the largest terrestrial sink for carbon on the planet. The ability of agriculture lands to store or sequester carbon depends on several factors, including climate, soil type, type of crop or vegetation cover and management practices. Additional studies considering the role of carbon payments in the capacity of farmers to cope with risk are needed.

CONCLUSIONS

Agriculture has a significant task to play towards an effort to mitigate the climate change due to atmospheric enrichment of CO₂ and other greenhouse gases. Scientific agriculture can be a solution to environmental issues but especially to reducing the rate of enrichment of CO₂ in the atmosphere. Recommended management practices include conversion from plow till to no-till, incorporation of cover crops and forages in the crop rotation, nutrient management including compost/manures and judicious use of fertilizers. Hence, 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. Moreover, implementation of these practices will generally sequester more C in agricultural soils.

REFERENCES


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