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Effect of shelterbelt and land management on soil carbon sequestration in shelterbelt-pasture system at Charles Sturt University, Orange campus.

Abstract

Measurements of soil organic carbon (SOC) levels were made on soils from 0 - 10cm and 10 - 20cm soil depth that were collected from three 12 - year old shelterbelts integrated with pastures in new South wales, Australia to determine whether there was any effect of shelterbelts on SOC levels in the adjacent shelterbelt. The samples were collected in the spring (September 2011) and autumn (March 2012) at increasing distance from the midpoint of shelterbelts. To determine the SOC level in the sample, two permanganate oxidisable methods were used: the Weil et al. (2003) method and the Blair et al. (1995) method. Regression analysis of our result indicated no significant difference ($P>0.005$) in SOC along the sampling points in an increasing distance from the midpoint of the shelterbelts in both seasons. However, there was a significant difference ($P<0.005$) in SOC level between the two depths. Also, we recorded a higher SOC level in the autumn sampling than the spring sampling.

Keywords: shelterbelt, pasture, Soil organic carbon, carbon sequestration.

Introduction

The importance of organic carbon with respect to the physical, chemical and biological aspect of soil quality is well established. In addition to organic carbon being a crucial sustainability factor in temperate, as well as tropical land use. Soil organic carbon (SOC) sequestration is also an efficient path way for mitigating agricultural CO_2 emission and even in reducing anthropogenic emission of CO_2 (Lal, 2008). Labile organic carbon is a critical component of SOC because of its intimate association with soil microbial respiration and role in the decomposition of resistant soil organic matter (SOM) (Feng et al., 2011).

All agricultural soils have been altered from their natural state by human interventions which are designed to maximizing production functions and which, to some degree, result in a loss of other ecosystem functions (Saunders, 1992). After the natural vegetation has been cleared to establish agricultural fields, all the major soil properties that describe its health are changed, largely negatively. The decline in soil organic matter content starts immediately after clearing and the initiation of cultivation, after a period of continuous cultivation they reach a new dynamic equilibrium (Oldeman, 1994).

There is evidence that conservation practices, well-managed pasturelands, planted forests, and agroforestry systems can considerably reduce carbon loss, maintaining SOM levels or even increasing them (Freitas et al., 2000). Since SOM has no definite chemical composition, SOC has been measured to indicate soil health (Weil et al., 2003). Soil organic carbon stock and pools are usually highly variable on both spatial and temporal scales (Allen et al., 2010). The presence of SOC

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at any location is influenced by complex interactions among plant growth, climate, soil type or parent material, topography and site management.

Attributes such as increase water–holding capacity, higher infiltration rates and higher nitrogen availability arising from increased SOC can enable farming system to be more resilient to climate change (NSW Industry and Investment, 2010).

Land management can have enormously different effects on various carbon pools. Long-term studies have shown that continuous cropping results in decline of SOC levels, however, the rate and magnitude of the decline depends on the prevailing climate and soil condition and can be improved by prudent soil management practices. These include manure additions, adequate fertilization, return of crop residues to the soil, and most importantly, conservation tillage coupled with intensive cropping systems, and rotations which include pasture or ley periods (Reeves, 1997).

Storing carbon in soil (soil carbon sequestration) is a key process in relation to global warming and climate change, which is believed to be caused primarily by elevated concentration of atmospheric CO_2 with other greenhouse gases. Soil carbon sequestration restores degraded soils, enhances biomass production, purifies surface and ground waters, and reduces the rate of enrichment of atmospheric CO_2 by offsetting fossil fuel emissions (Lal, 2004). Every tonne of carbon sequestered in the soil is a tonne of carbon reduced from the atmosphere, so good management of soil carbon is an important tool in the reduction of greenhouse gases in the atmosphere. Soil carbon sequestration is vital in agricultural systems and it is gaining global attention because of the growing concern to reduce the rapidly increasing atmospheric CO_2. Follett et al., (1998) estimated the potential carbon sequestration in pasturelands and rangelands in USA and concluded that half of the sequestration was derived from changes in pasture management, i.e. fertility management, application of manure, improved pasture species, and grazing management. The present study examines shelterbelt and pasture management and the extent to which they can be used to sequester soil organic carbon.

The objective of this study was to compare the quantity of labile carbon and total organic carbon in soils managed under long term pasture and adjacent soil under shelterbelt plantings of native species at different depths.

MATERIAL AND METHODS

Study site and experimental design

The study was done at the Orange campus of Charles Sturt University (33°15'S; 149°07'E; 875 m above sea level (asl) in the central Tablelands of New South Wales. Soil types range from red–brown silty clay loam dermosols along the mid–lower slopes to red chromosols along the upper slopes and ridges (Kovac, Lawrie, 1990). From the records of the weather station of the University Campus,(Bureau of Meteorolgy, 2011) the climate is characterized by cold—wet winters (2—10℃) and mild summers (12—25℃). Usually, rainfall occurs uniformly through the year (700—950 mm/a). Mean-monthly maximum temperatures in 2011 ranged from 15.1 to 18.4℃ in 2011 indicating that temperatures were warmer than the comparable 30-year average of 15.6℃; average rainfall was 603.4 mm in 2011, nearly 90 mm more than the preceding 30-year.

Three shelterbelts (*Leeds Parade*, *College 4*, and *Weston 1*; hereafter referred as Sites 1, 2, and 3, respectively), each about 100 m long and 15—25 m wide, established in 1998—2000 and situated within previously established pasture land, were used (Fig. 1). The mean above-sea elevations are 885m asl for Sites 1 and 2, and 907 m for Site 3. These sites were chosen for their similarity in being narrow, elongated shelterbelts with a northerly—southerly orientation, receiving the same easterly downwind, in which the sampling transects were constructed. The principal purpose of establishing these shelterbelts with a mixture of seedlings of Australian native trees was to capitalize on the advantages the shelterbelts provide when occurring in a pasture ecosystem of perennial-pasture taxa. Populations of Poaceae and Fabaceae were the principal species in the pasture. Population of

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Boraginaceae occurred in fewer numbers than the previously listed taxa of Poaceae and Fabaceae. Shelterbelt taxa include; Myrtaceae, Mimosaceae, Casuarinaceae, Myrtaceae and large native shrubs.

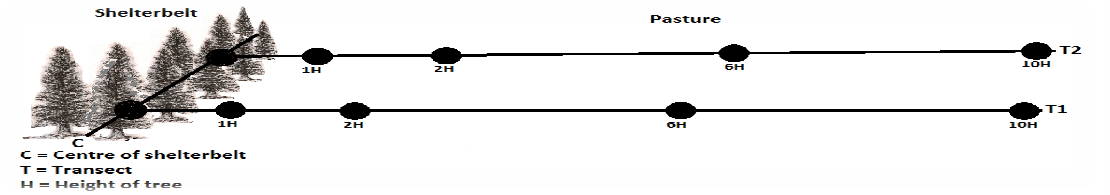

Figure 1: Layout for soil sampling in each shelterbelt-pasture system (Not to scale)

Table 1: Types of trees and grass specie at the study site.

	Tree Specie	Grass Specie
Leeds Parade	*Eucalyptus blakelyi, , E. macrorrhyncha, E. viminalis, A. implexa, A. vestita, Casuarina cunninghamiana, Callistemon sieberi*	*Phalarisaquatic, Trifoliumsubterraneum, Vulpiabromoides*,
College 4	*Eucalyptus blakelyi, E. melliodora, E. pauciflora, Acacia dealbata, A. vestita, Callistemon sieberi*	*Loliumrigidum, Holcuslanatus, Trifoliumrepens, Echiumplantagineum*
Weston 1	*Eucalyptus blakelyi, , E. macrorrhyncha, Acacia dealbata, A. implexa, Casuarina cunninghamiana, Leptospermum myrtifolium*	*Phalaris aquatic, Loliumrigidum, Loliumperenne,Hordeumglaucum*

Due to minor differences at the times of planting, the mean-tree heights of plants at Sites 1, 2, and 3 varied from 4.6 to 6.4 m. Therefore, average tree heights at each site were used as a pertinent measure to determine the distances for various sampling points to extract soil samples at two different depths. Tree heights were determined by obtaining average clinometric readings for randomly selected 15 trees, following the procedure described by the Department of Environment & Climate Change (2010).

Two parallel-running transects (T_1, T_2) situated at 90° to the midline of the shelterbelt, separated by a distance of 30 m, were constructed at Sites 1, 2, and 3. Five sampling points, named Zero, 1H, 2H, 6H and 10H, starting from the midline of each shelterbelt were used (Fig. 1). The mean tree height at Site 1 was 4.6 m; that at Site 2 was 6.4 m, and that at Site 3 was 5.6 m; the sampling points — the distance variables — 1H, 2H, 6H and 10H, were calculated based on mean tree heights. Two of the five sampling points (zero and 1H) fell within the shelterbelt vegetated area; the remaining sampling points fell within the adjacent pasture (figure 1). A maximum of the equivalent of 10 tree heights was chosen as the most-distant sampling point, following Cleugh, (2003).

Soil Sampling and Soil organic carbon and Total organic carbon analysis

Soil samples were collected in September, 2011 for spring sampling and in March, 2012 for autumn sampling from three shelterbelt-pasture sampling sites. The vegetation and litter fall were removed from the sampling points and the soil samples were taken at 0-10 cm and 10-20 cm depth using a soil auger of 10cm diameter. The soil samples were put in paper bags and labelled. The soil samples were crushed and rock and plant materials were removed before drying at 40℃ for 24 hr. in a desiccator. Additional soil sampling was done at every sampling point with soil cylinder to obtain intact soil core for bulk density measurements.
To measure different fractions of SOC: liable carbon and TOC in shelterbelt-pasture system at Charles Sturts University paddock in Orange Campus, the $KMnO_4$ oxidation methods of Weil et al., (2003) and Blair et al., (1995) were followed respectively.

Results and Discussion

Regression analysis for percentage of labile C and TOC were carried out using GenStat for Windows (Payne et al., 2003) for both spring and autumn samplings. For spring sampling, the TOC% showed no significant difference ($p > 0.005$) between shelterbelt and pasture sampling points along transacts

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at 0-10 cm depth for all three sites (Leeds Parade, College 4 and Weston 1). Similarly, there was no significant difference ($p > 0.005$) of TOC% along the transect for all sampling sites at the 10-20 cm depth. The TOC % ranged from 0.8% to 1.5% at 0-10cm depth and from 0.2% to 1.3% at 10-20cm depth with the mean of 1.1%, 1.1% and 1.4% at 0-10cm depth and of 0.9%, 0.4% and 1.2% at 10-20cm depth for Leeds Parade, Collage 4 and Weston 1 respectively (Table 2). However, there was a slight increase of TOC% at 10-20 cm depth from shelterbelt to pasture (see figure 3).

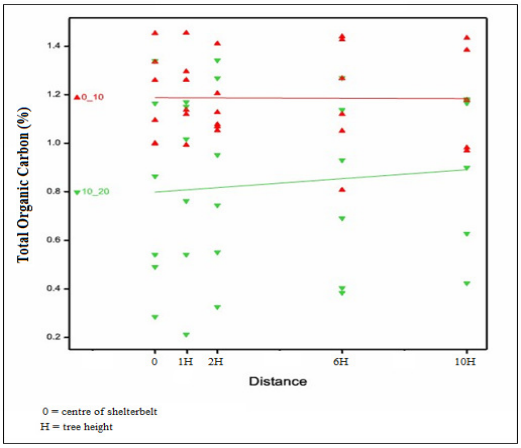

Figure 2: GenStat output of fitted and observed relationship for TOC%. (Spring sampling)

The percentage of liable carbon showed similar trend as in TOC in spring sampling. There was no significant difference ($p > 0.005$) of liable carbon percentage along the transect from the shelterbelt to pasture at 0-10cm depth which varies from 0.05% to 0.06%. Moreover, there was no significant difference ($p > 0.005$) of percentage liable carbon at 10-20 cm depth along transect from shelterbelt to pasture paddock which ranged from 0.03% to 0.06% (see figure 3). However, there were significant differences between both TOC% and labile C%, and sites ($p<0.001$), depth ($p<0.001$) and site-depth interaction ($p<0.001$) were also significant.

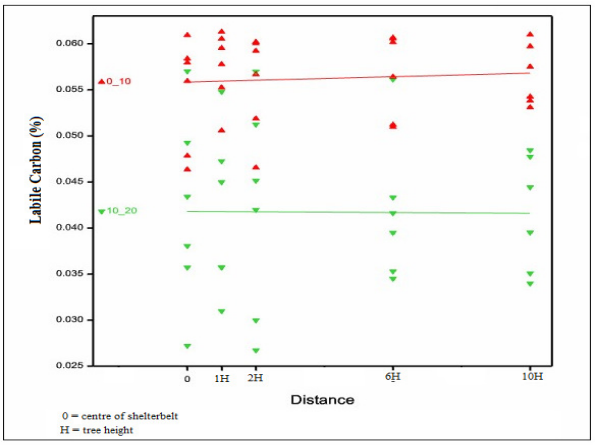

Figure 3:GenStat output of fitted and observed relationship for labile carbon. (spring sampling).

Table 2.The mean of TOC% and labile C% for spring and autumn sampling.

Site	TOC %				labile C %			
	Spring		Autumn		Spring		Autumn	
	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm
Leeds Parade	1.083	0.853	1.111	0.908	0.052	0.036	0.054	0.046
Collage 4	1.091	0.430	1.146	0.968	0.051	0.038	0.054	0.043

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Weston 1	1.384	1.219	1.386	1.209	0.049	0.051	0.061	0.054

The seasonal difference between the mean value of TOC% and labile C%, indicates that the TOC% in autumn was higher than that of spring (see Figure 2 and Figure 3) and particularly Collage 4 site showed significantly lower TOC% in spring (mean 0.43%) than that of autumn (mean 0.97%) (Table-2).

From our result and analysis provided, it is clear that the TOC and labile C% did not change significantly along transects and hance the shelterbelt did not have significant effect on the mass of carbon in the adjacent pasture paddock. According to Paul et al., (2002), the age and type of shelterbelt tree significantly affect the change in soil carbon down to 30cm depth. The changes in soil C was found to be declining (-3.25%) under 7 years old trees, while 4.37% increased under 26 years old trees at 0-10cm depth. For 10-20cm depth, the change in carbon was 0.24% increased with 7 years old trees and 11.39% increased with 30 years old trees from around 100 observations (Paul et al., 2002). Therefore, it can be concluded that the shelterbelt under investigation the trees were still young (10 years) to have effect on the mass of carbon sequestration in the shelterbelts and pasture paddocks. The effect of tree species is also an important factor to consider. For trees under 10years old, there was only a little change (0.23%) in soil carbon under eucalyptus compared to hard wood (4.67%) such as poplar (*Populous angustifolia*) and mahogany (*Swieteniamahagoni*) and decreased (2.39%) under pine (*Pinus radiate*) (Paul et al., 2002). The tree density at Leeds Parade shelterbelt was 20 plants m^{-2} and dominated by eucalyptus (50%) with larger canopy coverage, tree density at Collage 4 was 9 plants m^{-2} with pure eucalyptus (100%), and Weston 1 with 14 plants m^{-2} and dominated by acacia (70%) with understory shrubs. In addition to the shelterbelt species, the topography of the sites was also different: The mean above-sea elevations are 885 m (asl) for Sites 1 and 2, and 907 m for Site 3. Furthermore, the shelterbelts at Leeds Parade and Collage 4 are located down the hill, the transect therefore move towards the top of the hill unlike that of Weston 1 wherein the shelterbelt is located on top of the hill, and the transects moves down the hill. Therefore, the shelterbelt species and topography might contribute to the significant difference of TOC% and labile C% at the three sites of the shelterbelt and pasture paddocks. The finding of Lodge and King (2006) is consistent with our result due to the fact that the values of TOC in autumn were higher than that of spring when measured in a pasture. The result of lower carbon in 10–20 cm depth is consistent with the finding reported by Parfitt et al. (1997) in New Zealand that 43.3 Mg ha^{-1} at 0–10 cm depth and 31.7 Mg ha^{-1} at 10–20 cm depth under pasture. From table 2, the mean TOC at 0-10 cm depth for spring sampling is 17.7 Mg ha^{-1} and the mean TOC at 10-20 cm depth is 14.9 Mg ha^{-1}.

Conclusion

The TOC and labile-carbon has not changed significantly among sampling points along the transect as we move from the shelterbelt into the pasture paddock. However, both fractions of carbon decreased with depth. This is as result of the fact that SOC levels are dynamic and generally decline with depth because most sources of organic matter from which it is derived are either on the surface or near the surface of the soil and because plant roots are less dense as they grow deeper into the soil. Moreover, there was significant difference between sampling sites- Weston 1 site showed higher level of carbon than Leeds Parade and Collage 4. This may be attributed to topographic difference among the sites. The transect at Weston 1 moves down the slope while those for the other two sites move up the slope. In addition the proportion of carbon was higher in autumn sampling than spring sampling, which reflect the higher vegetation, microbial activity and warmer climate in autumn.

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