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# Assessment and Comparison of Soil carbon pool under Silvo-pastoral Agroforestry system in the North Wales, UK

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**Abstract -** As result of increased emission of green house gases, especially increased emission of Co2, Climate change is the main global challenges that many countries are facing. Increasing carbon sequestration through a forestation, reforestation and appropriate land use practices are considered as means to sink the atmospheric Co2 in terrestrial ecosystem. Agroforestry is recognized as a strategy for soil carbon sequestration (SCS) under the afforestation/reforestation activities in different parts of the world.However, little information is available on soil carbon dynamics under agroforestry systems. This study was aimed to determine the soil organic carbon pool under silvo-pastoral agroforestry system. The study was conducted at Henfeas research center in the north Wales, UK where Sycamore (Acer pseudoplatanus L.) and Red alder (Alnus rubra) were planted in 1992 in integration with the grasslands. The soil samples were collected to the depth of 30cm at different depth intervals (0-10, 10-20 and 20-30cm) under five treatments: under and outside the canopy of both Sycamore (Acer pseudoplatanus L.) and Red alder (Alnus rubra) and under the control grassland. The concentration of soil organic carbon (SOC %) under each treatment were analyzed using LOI (loss on ignition method) where soil samples were burned at 450 oc. The regression formula (Y= 0.458X-0.4 Where, Y= SOC (%) and X= SOM (%)) developed by Ball, 1964, was used to convert soil organic matter to SOC. It was identified that SOC concentration were significantly different at (P<0.05) between the treatments and along the soil profile.

**Keywords-** SOC, climate change, land use, Soil, Co2 emissions, decomposition, microbial activity

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## 1. Introduction

Climate change is the biggest global challenges affecting environmental, economical and social welfare throughout the world (IPCC, 2007). The latest assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007) projected that global average temperatures in 2100 will be between 1.8 and 4.0 °C higher than the 1980–2000 average. Precipitation will also expect to be increased by 2.29% at the end of the century. On the other hand, sea levels are expected to increase to 0.59 meters by 2100 based on observed rates of ice flow from Greenland and Antarctica.

Increased emissions of green house gas (GHG) to the atmosphere are the main causes for the Climate change to be happened (IPCC, 2007). According to this report, emissions of GHG due to anthropogenic activities like from different factories, and land use change contributes significant amount for the increased GHG specially the concentration of $CO_2$ in the atmosphere. Studies by (Paustian et al., 2000) also suggested that, Climate change is usually attributed to the extreme use of fossil fuel by industrialized countries and the conversion of forests to agricultural and urbanization in the developing or poor countries. Soil is the most important feature where large amount of Soil organic carbon (SOC), which is originated from plants and animal tissue that exist in different stages of decomposition, can be stored (Lal et al., 2001). It was estimated that soils contain more than three times the atmospheric pool and more than four times the biotic pool of carbon

There are different land use management practices suggested to boost the capacity of soil to store carbon. This include conversion of marginal agricultural land to perennial vegetation, applying different, soil management practices like mulch farming, reduced tillage, integrated nutrient management (INM), and integrated land management like introduction of agroforestry system Freeman et al. ,(2004). They found that agroforestry practices are the most important land use system in enhancing both above and below ground carbon storage.

### 1.2 Soil carbon pool potential in UK

According to the study by Bradley et al.,( 2005) , Soussana et a.,(2004) and UK country soil survey report in 2007, most of terrestrial carbon pool in UK is found below ground up to 30cm depth . The total soil carbon pool was estimated by integrating soil series databases and land cover in the country. According to these reports, the total amount of carbon in the soils of UK was estimated to be

9.8 ± 2.4 billion tones where 6.9 billion tones in Scotland and 2.8 billion tones in England and Wales.Intergovernmental Panel on Climate Change (IPCC, 2007) also suggested that, the UK's Climate Change act committed to cut 80% of greenhouse gases (GHGs) by 2050 so as to achieve the commitments to stabilize the atmospheric carbon dioxide to below 400PPm and the global average temperature rise to 2°C. In the some report, the UK government also has planned for a low carbon transition in agriculture to voluntarily reduce 6-11% of GHG. Increasing the level of soil organic carbon levels as climate change mitigation strategy was largely being ignored by climate policymakers and analysts in the UK, partly due to the inadequacies of the current agricultural GHG accounting systems (Smith P.,2008). However, recently encouraging agreements have been made at the European level to reduce agricultural greenhouse gas emissions by at least 20% by 2020, primarily by storing carbon in the soil (EU Agriculture Commissioner :Mariann Fischer Boel, September, 2009). Currently, the UK Government published strategy to safeguard soil carbon pool acknowledged that preventing emissions from soil and exploring how to increase existing stores of soil carbon can make an important contribution to meeting the Government's emission reduction targets and carbon budgets.

## 1.3 Rationale of the study

The environmental, economical and social potential advantage of agroforestry was highly pronounced now days in both temperate and tropical climatic zones. The study by Sinclair F. et al, (2000) and Young, 1997) suggested that agroforestry system provide very diversified benefit like to enhance biodiversity in certain landscapes, to reduce soil erosion and nitrate leaching in intensively managed agricultural landscapes and it enable farmers to cultivate poor soils as arable land by enhancing soil organic matter, improving water holding capacity, and increasing nutrient inputs through nitrogen fixation. This study also indicated that, when agroforestry is immediately established after slash and burn agriculture, 35% of the original forest carbon stock can be restored in improving soil quality and quantity through organic inputs from crop residues and tree litter resulting in the maintenance or increase of soil organic matter (SOM).

International Panel on Climate Change (IPCC 2007 ) estimated that the current total area under agroforestry is 400 million ha that have a potential to store 0.72 Mg $ha^{-1}$ $year^{-1}$ of carbon (Watson et.al. ,2000). However, the impact of any agroforestry system on soil carbon sequestration mainly affected by the amount and quality of biomass input available by tree, grasses and soil properties that significantly alters the rate of turnover of organic matters Nair *et al*., ( 2009).

In silivo-pastoral agroforestry practices, there is close interaction between trees and pasture that attribute the system to be the largest potential to sequester carbon in both above and below ground to offsets greenhouse gas emissions associated with deforestation and shifting cultivation (Richard T. Conant e*t al*., 2001). Silvo-pastoral agroforestry is widely practiced in temperate region including in Uk where timber and sheep production are integrated (Buck *et al.*, 1999). The incorporation of trees on farms affects carbon stocks differently compared to a single cropped area since trees are important in key processes such as nutrient cycling (Watson *et al.*, 2000).

Now days, research in temperate and tropical agroforestry systems has focused on role of agroforestry in soil and water conservation, crop and pasture productivity, and nutrient cycling. However, little information is available on role of agroforestry systems in soil carbon dynamics and its potential to store SOC Oelbermann et al., (2007). On the other hand the losses of soil organic carbon (SOC) from forest and grassland due to different anthropogenic activities were studied and documented but there is knowledge gap on whether or not SOC under forest and grass vegetation differs (Barker et al., 1996). This project is required to provide understandings on contribution of silvo-pastoral agroforestry practices in increasing SOC.

## 2. Research Objectives

1) To quantify and compare the amount of carbon stored under different tree species and grassland in silvo-pastoral agroforestry system

2) To determine the total carbon pool and changes with the depth of soil profiles under the silvo-pastoral agroforestry system.

## 3. Materials and Methods

### 3.1 Study area:

The Henfaes experimental site is one of a national network of six sites established across the country investigating the potential of silvo-pastoral agroforestry in UK farms (Sibbald and Sinclair, 1990). It was established in 1992 on 14 ha of agricultural land at the University of Wales, Bangor farm (Henfaes), which is located in Abergwyngregyn, Gwynedd, 12 km east of the

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city of Bangor. The climate is hyper oceanic, with an annual rainfall of about 1000 mm. The soil is a fine loamy brown earth which was classified as a Dystric Cambisol in the FAO systems of classfication. Topography consists of a shallow slope on a deltaic fan of approximately 1-2$^0$ and the aspect is north-westerly, at an altitude of 4-14 m above sea level.

According to the study report by Teklehaimanot and Sinclair, (1998), the depth of the water table ranges between 1 - 6 m. The entire site was sown to a mixture of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) in April 1992 at a seed rate of 12.5 kg ha$^{-1}$ of *L. perenne* var. Talbot, 12.5 kg ha$^{-1}$ of *L. perenne* var. Condessa, 2 kg ha$^{-1}$ of *T. repens* var. Gwenda and 2 kg ha$^{-1}$ of *T. repens* var. S184.

This experimental site has a common set of core treatments described by Sibbald and Sinclair (1990). These comprise sycamore (*Acer pseudoplatanus* L.) planted at 100 and 400 stems ha$^{-1}$ into grazed pasture and at 2500 stems ha$^{-1}$ without grazing as a farm woodland control, and pasture without trees as an agricultural control. There are also additional treatments at the Henfaes site: red alder (*Alnus rubra* Bong.) planted at 400 stems ha$^{-1}$ into grazed pasture and at 2500 stems ha$^{-1}$ without grazing as a farm woodland control, and sycamore (*Acer pseudoplatanus L.*) planted at an overall density of 400 stems ha$^{-1}$ integrated with grazing pasture.

### 3.2 Experimental design

This experiment was conducted in agroforestry research experiments where grassland integrated with both sycamores (Acer pseudoplatanus L.) and red alder (*Alnus rubra)*. These trees were planted 18years ago (in 1992) with the spacing of 400stems per hectare. Both sycamore (*Acer pseudoplatanus L.)* and red alder *(Alnus rubra)* were planted in separated plot integrated with grazing pasture in strip arrangements.

The experiment had five treatments with seven replications from which soil samples were collected. The treatments were:

1. Under the canopy of Sycamore *(Acer pseudoplatanus L.)*
2. Outside the canopy of Sycamore (Acer pseudoplatanus L.) )
3. Under the canopy of Red alder (*Alnus rubra)*
4. Outside the canopy of Red alder *(Alnus rubra)*
5. Control (under grassland without trees)

### 3.3 Soil sampling

Soil samples were collected from both under and outside the canopy of sycamore *(Acer pseudoplatanus L.)* and red alder *(Alnus rubra)* and from the control (grassland with no trees). For this experiment, seven stems or trees were randomly selected for each species. The sample plots under and outside of the canopy of both trees were arranged in a perpendicular to each other. Soil samples were collected from under the canopy of both trees and from the mid points of the grass strip that is parallel to the selected stem. For soil sampling under the control (grassland with no trees), the transect line was drown starting from the center boundary line. The samples were taken from seven different points along the transect line.

For soil sampling under the control, the transect line was drown starting from the center boundary line. The samples were taken from seven different points along the transect line.

Soil samples were taken to the depth of 30 cm at different depth interval (0-10, 10-20, 20-30cm). This depth was to which SOC is most likely affected due to land use change and this sampling technique was also used in many similar studies to assess the soil carbon pool under different land use system.

### 3.4 Soil organic carbon analysis using loss on ignition method (LOI)

The soil samples were oven dried at 105 $^{o}$c for 24 hours to remove the moisture. The dried samples were grinded and sieved to 2 mm size to remove large particles (generally those particles greater than 2-mm in diameter) to make the samples homogenous for further analysis.

The loss-on-ignition (LOI) method was used for the determination of soil organic matter content. About 20gm of oven dried soil sample was added to a ceramic crucible (or similar vessel). The samples were then heated to 450$^{o}$C overnight (16hrs) to remove all soil carbon (Ball, 1964).
%SOM (Soil organic matter) = (Weight of oven dried-weight after burning) /weight of oven dried X 100. Finally, the loss-on-ignition (LOI) method determines only the organic matter content in the soil. For the sample burned at the temperature of 450$^{o}$c, there was the regression formula or correction factor developed by (Ball, 1964) to convert soil organic matter (%) to SOC (%).
The result was calculated by using this regression formula: Y= 0.458X-0.4, Where, Y= SOC (%) and X= SOM (%) or LOI (%).

## 4. Data analysis

The data collected during the experiment were analyzed using SPSS16.0 statistical software. Depending on the characteristics of the variables assessed and the distribution of the data, one way and two-way analysis of variance (ANOVA) was used for the analysis to test differences in soil organic carbon (SOC) among the treatments and soil profile. The differences in Soil chemical and physical properties across the treatments and soil profile or depth were also tested at statistically different parameters ($p<0.05$). Post-hoc tests (Tukey HSD) were used to further compare the treatment means. Correlation analyses were also carried out to detect functional relationships among key soil variables (soil pH, bulk density and moisture content) and their interaction with the change in SOC.

## 5. RESULT

### 5.1 Soil organic carbon (SOC) content under Silvo-pastoral agroforestry system

The SOC content was analyzed for each treatment. The mean and standard error of mean for SOC (%) and other soil properties under each treatment were analyzed and summarized in table 1. Fisher's least significant difference (LSD) was used to test the significance difference of means that were considered significantly different at $\alpha$=0.05 probability level table 2. Based on this analysis, the Mean difference in SOC was highly significant at ($P<0.05$) between control grassland (CGL) and the rest of the treatments (outside and under the canopy of both sycamore *(Acer pseudoplatanus L.)* and red alder *(Alnus rubra)* .However, SOC content was not significantly different at ($P>0.05$) between outside and under the canopy of both red alder *(Alnus rubra)* and sycamore *(Acer pseudoplatanus L.)*.

Table 1: Mean ± standard error of mean of SOC, pH, bulk density and moisture content under each treatments

| Treatments | Different Soil propertie | | | |
|---|---|---|---|---|
| | SOC (%) | pH | Bulk density (g/cm$^3$) | Moisture ontent (%) |
| Under control grassland | 0.89 ±0.61 | 6.74± 0.40 | 2.43±0.15 | 10.76±2.48 |

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| | | | | |
|---|---|---|---|---|
| Outside the canopy of red alder | 4.30±1.74 | 5.03±0.05 | 1.90±0.26 | 12.73±1.88 |
| Outside the canopy of sycamore | 4.51±1.90 | 5.24±0.10 | 1.46±0.05 | 16.73±2.21 |
| Under the canopy of red alder | 6.39±2.88 | 4.98±0.08 | 1.56±0.31 | 18.0±2.78 |
| Under the canopy of sycamore | 5.81±2.59 | 4.93±0.07 | 1.50±0.26 . | 18.60±2.97 |
| Ground mean | 4.30±2.77 | 5.38±0.20 | 1.77±0.42 | 15.38±3.83 |

Table 2: Multiple Comparisons of the mean difference of SOC content between the treatments using Fisher's least significant difference (LSD)

| Treatments | | Mean Difference [a] | Sig. level |
|---|---|---|---|
| Control grassland | Outside canopy of red alder | -3.80600[a] | .045 |
| | Outside canopy of sycamore | -4.01967[a] | .041 |
| | Under canopy of red alder | -5.89733[a] | .006 |
| | Under canopy of sycamore | -5.31733[a] | .011 |
| Outside canopy of red alder *(Alnus rubra)* | Control grassland | 3.80600[a] | .045 |
| | Outside canopy of sycamore | -.21367 | .903 |
| | Under canopy of red alder | -2.09133 | .251 |
| | Under canopy of sycamore | -1.51133 | .399 |
| Outside canopy of sycamore (*Acer pseudoplatanus L.)* | Control grassland | 4.01967[a] | .041 |
| | Outside canopy of red alder | .21367 | .903 |
| | Under canopy of red alder | -1.87767 | .300 |
| | Under canopy of sycamore | -1.29767 | .467 |
| Under canopy of red alder *(Alnus rubra)* | Control grassland | 5.89733[a] | .006 |
| | Outside canopy of red alder | 2.09133 | .251 |
| | Outside canopy of sycamore | 1.87767 | .300 |
| | Under canopy of sycamore | .58000 | .742 |

| | | | |
|---|---|---|---|
| Under canopy of sycamore *(Acer pseudoplatanus L.)* | Control grassland | 5.31733[a] | .011 |
| | Outside canopy of red alder | 1.51133 | .399 |
| | Outside canopy of sycamore | 1.29767 | .467 |
| | Under canopy of red alder | -.58000 | .742 |

The Mean difference is significant at P< 0.05.

**5.2 Soil organic carbon analysis at varies depth intervals**

The SOC content of soil was significantly different with the depth at (P<0.05) (See table 3 below). The Mean difference was highly significant between the depth intervals (0-10cm) and (20-30cm). However, the mean difference in SOC (%) was not significantly different at (P>0.05) between 0-10 and 10-20cm depth intervals.

The trend of SOC (%) content along the soil profile was analyzed for each treatment figure 1. Accordingly, Mean of SOC under the canopy of red alder *(Alnus rubra)* is higher than the rest of the treatments while SOC under control grassland is much lower than other treatments.

Table 3: Multiple Comparisons of the mean difference of SOC content between the depth intervals using Fisher's least significant difference (LSD)

| Depth (cm) | | Mean Difference | Sig. level |
|---|---|---|---|
| 0-10 | 10-20 | 2.19360 | .177 |
| | 20-30 | 3.86340[a] | .027 |
| 10-20 | 0-10 | -2.19360 | .177 |
| | 20-30 | 1.66980 | .296 |
| 20-30 | 0-10 | -3.86340[a] | .027 |

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| | | | |
|---|---|---|---|
| | 10-20 | -1.66980 | .296 |

**a.** The Mean difference is significant at P< 0.05 level

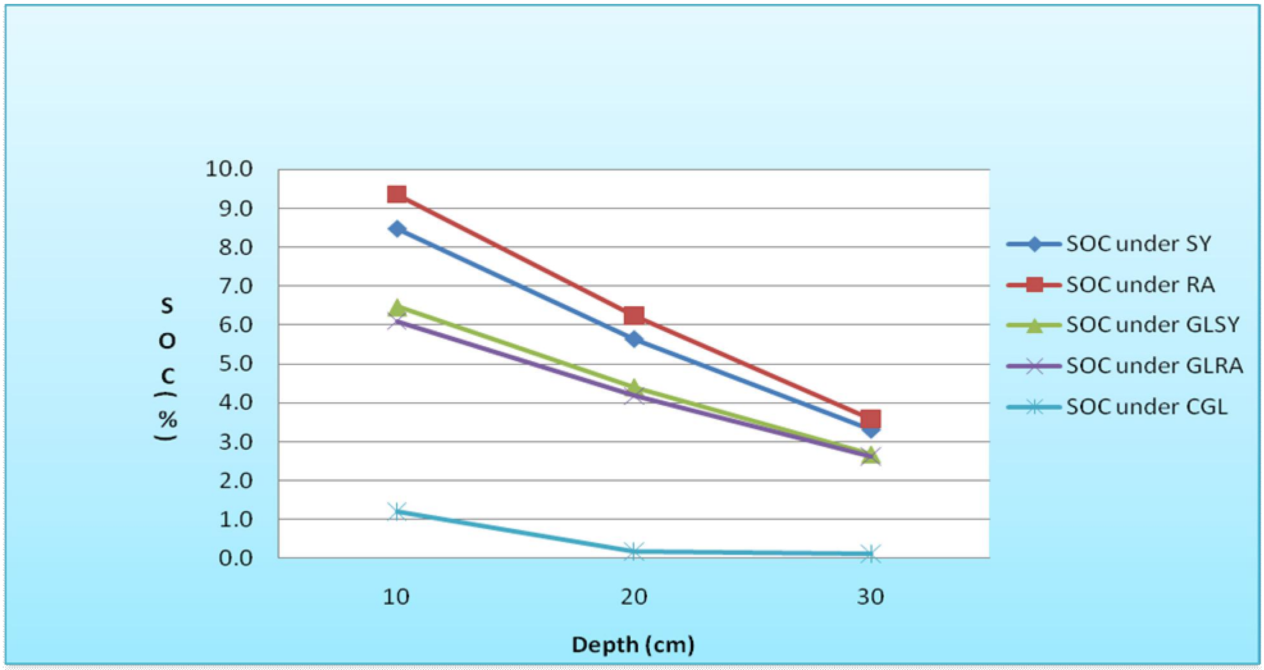


Figure 1: Variation of soil carbon pool at different depth interval under and outside the canopy of both sycamore *(Acer pseudoplatanus L.)* and red alder *(Alnus rubra)* and under the control grassland

Table 4: Mean ± standard error of SOC, pH, bulk density and moisture content in varies depth intervals

| Soil depth (cm) | Soil properties | | | |
|---|---|---|---|---|
| | SOC (%) | PH | Bulk density(g/cm$^3$) | Soil moisture content (%) |
| 0-10 | 6.32±3.16 | 5.19±0.22 | 1.56±0.44 | 17.96±3.99 |
| 10-20 | 4.12±2.37 | 5.30±0.34 | 1.79±0.40 | 15.02±2.92 |
| 20-30 | 2.46±1.37 | 5.65±0.48 | 1.95±0.41 | 13.16±3.50 |
| **Ground mean** | **4.30±2.77** | **5.38±0.20** | **1.77±0.42** | **15.38±3.83** |

# 6. Discussion

## 6.1 Soil organic carbon (SOC) under silvo-pastoral agro forestry system

According to this study result, although carbon inputs were higher under the canopy of the trees i.e under the canopy of both sycamore *(Acer pseudoplatanus L.)* and red alder *(Alnus rubra*), soil organic carbon content was not significantly different among the agroforestry components or treatments except with the SOC under the control grassland table 2. SOC was significantly lower under the control grassland (on grassland without trees) as compared with the SOC concentration under and outside the canopy of both sycamores *(Acer pseudoplatanus L.)* and red alder *(Alnus rubra)* (under the silvo-pastoral agroforestry system where trees and grasses are integrated). Therefore, this experiment clearly showed that agroforestry land use contributes high significance to store SOC that could be one of the strategies in mitigating climate change or offsetting $Co_2$ emissions.

This experiment is highly complemented with the previous studies by (Nair and Kumar, 2009). These studies have suggested that agroforestry practices like silvo-pastoral systems are important for conserving and sequestering soil carbon due to the greater interactions between trees and pasture through facilitating carbon input or exchange between the systems. They also indicated that agroforestry land use systems have the potential to offset immediate greenhouse gas emissions associated with deforestation and shifting cultivation.

Some other authors tried to compare the total SOC under agro forestry system and grassland. They have showed that agroforestry have higher potential to sequester carbon than pastures and field crops (Kirby and Potvin, 2007, Haile et al., 2008). The amount of SOC stored under agro forestry system was also compared among other land uses by Watson et al., (2000). This study has suggested that, trees in agroforestry systems can store high SOC pool compared to mono cropped areas. The study also indicated that, agroforestry systems contain 50 to 75 Mg of carbon per hectare compared to row crops that contain less than 10 Mg of carbon per hectare.

Reviewing SOC content in agroforestry system in comparison with other land-use systems, Nair et al. (2009) tried to rank the land-use systems in terms of their SOC content in the order: forests > agroforests > tree plantations > arable crops including grasslands. In addition, IPCC report in

2000 also predicted the Carbon sequestration potential of different land use and management options up to 2040's .According to these report, agroforestry was the promising land use system to sequester high carbon to mitigate the climate change as compared with other land use practices.

Soil organic carbon concentration was significantly varied along the soil profile. It was higher in the upper 0–10cm of the soil layer as compared with the SOC content (10-20cm and 20-30cm) showing the decreasing trend with the depth under each treatments (See the SOC trend with depth in figure 1.

Studies by (Makumba et al., 2007) suggested that SOC content of the soil varies with the soil profile due to the fact that accumulation of organic matter from the litter fall, dead wood and branches is usually higher to the surface of the soil profile. Soil organic matter accumulation is generally higher to the first 0-20cm depth (Makumba *et al.,* 2007). Makumba and his colloquies also suggested that even though most of the tree roots occur to add substantial amounts of carbon from root exudates and fine-root turnover in the deeper soil layers, SOC content is low.

In this experiment, it was identified that the mean concentration of SOC (%) was higher under the canopy of red alder *(Alnus rubra)* where mean SOC to 30cm depth was 6.4% as compared with under the canopy of sycamore *(Acer pseudoplatanus L.)* (5.8%), outside the canopy of sycamore *(Acer pseudoplatanus L.)* (4.51%), outside the canopy of red alder *(Alnus rubra)* 4.3%, and under the control grassland (2.06%). The reason why SOC was higher under the canopy of red alder *(Alnus rubra)* is not clearly known but it could be due to the fact that red alder *(Alnus rubra)* can actively fix atmospheric nitrogen that is important to increase the biomass production and consequently used as an input for the increment of SOC in the soil (Teklehaimanot and Martin, 1998). This study showed that, red alder *(Alnus rubra)* was introduced at Henfaes to investigate the use of biological nitrogen fixation as an alternative to chemical fertilizer.

The study by (Jackson *et al.,* 2000) also suggested that, in silvo-pastoral agro forestry systems, where trees are allowed to grow in integration with grasses, there are high probability of altering the above- and belowground total productivity and changes in the quantity and quality of litter inputs. Such changes in vegetation component, litter, and soil characteristics modify the carbon dynamics and storage in the ecosystem.

The data analysis result in table 2 clearly showed that, trees positively affect the carbon pool potential under the grassland (outside the canopy of both red alder *(Alnus rubra)* and sycamore *(Acer pseudoplatanus L.)*. The mean SOC content outside the canopy of both red alder *(Alnus rubra)* and sycamore (*Acer pseudoplatanus L.)* were 4.30% and 4.51% respectively. These values are almost two times higher than the SOC content of the soil under the control pasture (2.06%) that was not integrated with any tree species. Therefore, from this result one can conclude that tree have appositive impact in increasing SOC under the grassland in silvo-pastoral agro forestry system. Studies also showed that the presence of trees have both positive impacts on the productivity of grazed pasture through shelter effects and improving soil fertility or increasing soil organic matter (SOM) (Sibbald et al. 1991) and negative impacts, through competition for light, water and nutrients (Sinclair et al. 2000).

**CONCLUSION AND RECOMMENDATIONS**

This study examined the contribution of silvo-pastoral agroforestry system to store soil organic carbon. It was identified that the integration of trees with grass in silvo-pastoral agroforestry system is important to sequester more soil organic carbon as compared with mono cropping system. On the other hand, soil organic carbon pools under the agroforestry components were compared. The result showed that red alder *(Alnus rubra)* could store more SOC than under sycamore *(Acer pseudoplatanus L.)* and grassland due to the nitrogen fixing potential of the red alder *(Alnus rubra)* that can facilitate the biomass production and consequently increase SOC contents of the soil. Based on the result of this experiment, SOC under the control grassland was by half lower than the SOC under the trees and grassland integrated with trees (sycamore and red alder).Therefore, this study clearly showed that, it is strongly recommended to incorporate silvo-pastoral agroforestry system as the min strategy to increase soil organic carbon in terrestrial ecosystem.

The study also identified that most of SOC at Henfeas agroforestry experimental site was found to the depth of 10cm showing the decreasing trend with the increased depth. Therefore, any soil disturbance to this depth can affect the SOC stored under this land use practice.

In order for countries to control against increasing atmospheric $Co_{2,}$ increasing carbon sequestration below ground in the form of SOC is crucial. However, there were different natural and anthropogenic factors that affect the carbon storage in the soil. This study identified some of these factors such as climate change, soil characteristics and disturbances or land use change. Land use changes are the main causes for the depletion of SOC and increased concentration of GHG in the atmosphere. In order to improve the SOC pool under different land uses, land management practices such as conversion of marginal agricultural land to perennial vegetation, introduction of agroforestry system and applying different soil management practices are important.

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