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# Evaluation of Soil Carbon Pool potential under different Land use system and Its Correlation with different Soil Properties in North Wales, UK

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## ABSTRACT

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 integration with the grasslands. It was aimed to determine the soil organic carbon pool under different land use system. The soil samples were collected to the depth of 30cm at different depth intervals (0-10, 10-20 and 20-30cm) having 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 °c. It was identified that SOC concentration were significantly different at ($P<0.05$) between the treatments and along the soil profile. In addition to SOC, soil pH, bulk density and soil moisture content of the soil under each treatment were determined to investigate the correlation between these soil properties with the SOC contents. It was identified that, soil pH and bulk density were significantly ($P<0.01$) and negatively correlated with SOC content under the treatments. SOC content decreased with the increased in soil pH and bulk density. On the other hand, soil moisture content and

SOC concentrations were significantly ($P<0.01$) and positively correlated indicating that SOC pool increased with the increased in soil moisture content**.**

**Key words/phrases:** SOC, agroforestry, climate change, land use, Soil, $Co_2$ emissions.

## 1. INTRODUCTION

Increased emissions of 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 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, 2001). It was estimated that soils contain more than three times the atmospheric pool and more than four times the biotic pool of carbon. Changes in amount of SOC with change in land-use have been getting significant attentions today due to the need to reduce emission of green house gases or sequester additional atmospheric carbon. There is strong evidence that increasing SOC pool could substantially offset fossil fuel emissions (Kauppi *et al*., 2001). SOC loss is usually higher in agricultural soil due to increased decomposition rate and frequent erosion of top soils (Ewert *et al*., 2005). On the other hand, due to a steady decline in livestock numbers and intensification of their production, application of manure organic matter to the soil reduced in UK (Burton and Turner, 2003).

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; Kasahun Kitila Hunde, 2015; Lal *et al*., 2004). This study also suggested that, agroforestry practices are the most important land use system in enhancing both above and below ground carbon storage.

The stock of SOC can be affected by soil chemical and physical characteristics (Banfield *et al*., 2002, Bonnett *et al.,* 2006). Soil properties like, CEC (cat ion exchange capacity), pH, soil moisture content, bulk density and soil types affects the activity of the soil decomposer community (micro-organisms, fungi and other invertebrates). Studies by (Smith et al., 2001) also indicated that, depletion of soil carbon pool affects soil physical, chemical and biological properties. According to these studies, soil physical degradation like reduction in aggregation, decline in soil structure, crusting, compaction and reduction in water holding capacity are the result of depletion of SOM. Soil carbon loss also resulted in biological degradation such as reduction in species diversity of soil fauna and decreased in biomass production which contribute to soil carbon pool (Lal, 2001). The decomposition of soil organic matter has very diversified impact on both environmental and socio economic conditions (IPCC, 2001).

The study by Bonnett *et al.,* (2006) observed that, in comparison to silt loam and sandy loam soils, coarser soils had lower total SOC concentration due to high microbial activities, which are responsible for the decomposition and release of carbon in sandy or coarse textures.

**Objectives of the study**

1. To evaluate the SOC pool under plantation forest and grassland
2. To determine the correlation of different soil characteristics and Soil carbon pool

## 2. MATERIALS AND METHODS

### 2.1. Study Area

The study was conducted at the Henfaes experimental site that was established as silvo-pastoral agroforestry research in 1992 on 14 ha of agricultural land under the University of Wales, Bangor. It is located in Abergwyngregyn, Gwynedd, and 12 km east of the 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. The depth of the water table ranges between 1 - 6 m (Teklehaimanot and Sinclair, 1993). 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.*).

### 2.2. Experimental design

This experiment was conducted in block-III of agroforestry research experiments (Figure 2). The block consist grassland integrated with both sycamore (Acer pseudoplatanus L.) and red alder (*Alnus rubra)*. These trees were planted 18years ago (in 1992) with the spacing of 400stems per hectare. 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)

### 2.3. 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 which 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 (See again figure 3). 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.

### 2.4. Soil sample analysis

The weights of wet soil samples were taken before they were oven dried at 105 $^{o}$c for 24 hours to determine the amount of moisture lost. 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. In addition to soil organic carbon content (SOC), the soil samples were analyzed for soil moisture content, soil pH and Soil bulk density.

### 2.5. Soil sample Analysis procedures (laboratory procedures)

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

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). 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 (%).

#### 2.5.2. Soil moisture content analysis

The moist sample was weighted using sensitive balance immediately after collected.The samples were oven dried at 105 $^{0}$c for 24 hours. After 24 hours, the dried the samples were weighted. To be sure that the moisture was removed, the samples were returned to oven dry for 6 hours and reweighted. This process was repeated until the weight does not change. Soil moisture content (gm) = (weight of wet soil-weight of oven dry soil). Weight of the tray (container was deducted from both wet and dry weight). Soil moisture content (SMC %) was calculated with the formula developed by Javadi and Hajiahmad, (2006): SMC (%) = (weight of wet soil –weight after oven dried)/ weight after oven dried * 100.

### 2.5.3. Soil bulk density analysis

Soil core sample was taken using 100cm$^3$ core sampler to the depth of 30cm (at depth intervals of 0-10, 10-20 and 20-30cm separately). Soil samples were oven dried at 105 0c for 48 hours. After 48 hours of drying, the dried core samples were weighted separately. Weight of the tray or container was deducted from the total dried weight. Soil bulk density was calculated as: Soil bulk density (g/cm$^3$) = weight of oven dried/volume (100cm$^3$).

### 2.5.4. Soil pH

25 gm of dried and sieved soil was mixed with 25 ml of distilled water in a clean beaker. The soil-water mixture was stirred for 30 seconds and then allowed the mixture to settle until a supernatant (clearer liquid above the settled soil) .The pH meter was calibrated prior to use by inserting the glass electrode in a buffer solution of pH 7 to read pH 7.The electrode was rinsed with the distilled water and placed in a buffer solution of pH 4 to read pH 4.The electrode was again rinsed with the distilled water placed in soil suspension to read its pH in scale of pH meter.

## 2.6. 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.

## 3. RESULT AND DISCUSSION

## 3.1. Soil organic carbon (SOC) content under plantation and grass land

The SOC content was analyzed for each treatment. Mean and standard error of mean of SOC, pH, bulk density and moisture content under each treatment was analyzed as it is indicated in the following table. 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). The Mean difference in SOC was highly significant at ($P<0.05$) between grassland (CGL) and the rest of the treatments (outside and under the canopy of both sycamore *(Acer pseudoplatanus L.)* and red alder *(Alnus rubra)*.

**Table 1**

Mean ± standard error of mean of SOC, pH, bulk density and moisture content under each treatment

| | | **Different Soil properties** | | |
|---|---|---|---|---|
| | | **pH** | **Bulk density (g/cm$^3$)** | **Moisture Content (%)** |
| Under grassland | 0.89 ±0.61 | 6.74± 0.40 | 2.43±0.15 | 10.76±2.48 |
| 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**
Comparison of SOC under each treatment using Fisher's least significant difference (LSD)

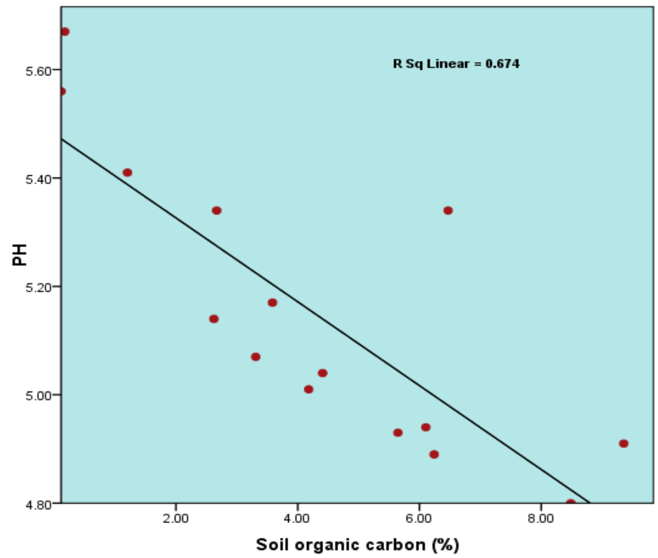
| Treatments | | Mean Difference | Sig. level |
|---|---|---|---|
| Control grassland | Outside canopy of red alder | .53333ᵃ | .018 |
| | Outside canopy of sycamore | .9733.87333ᵃ | .000 |
| | Under canopy of red alder | .87333ᵃ | .001 |
| | Under canopy of sycamore | .93333ᵃ | .001 |
| Outside canopy of red alder *(Alnus rubra)* | Control grassland | -.53333ᵃ | .018 |
| | Outside canopy of sycamore | .44000ᵃ | .041 |
| | Under canopy of red alder | .34000 | .101 |
| | Under canopy of sycamore | .40000 | .059 |
| Outside canopy of sycamore (*Acer pseudoplatanus L.)* | Control grassland | -.97333ᵃ | .000 |
| | Outside canopy of red alder | -.44000ᵃ | .041 |
| | Under canopy of red alder | -.10000 | .606 |
| | Under canopy of sycamore | -.04000 | .836 |
| Under canopy of red alder *(Alnus rubra)* | Control grassland | -.87333ᵃ | .001 |
| | Outside canopy of red alder | -.34000 | .101 |
| | Outside canopy of sycamore | .10000 | .606 |
| | Under canopy of sycamore | .06000 | .756 |
| Under canopy of sycamore *(Acer pseudoplatanus L.)* | Control grassland | -.93333ᵃ | .001 |
| | Outside canopy of red alder | -.40000 | .059 |
| | Outside canopy of sycamore | .04000 | .836 |
| | Under canopy of red alder | -.06000 | .756 |

The concentration of SOC under the plantation forest is higher than under the grass land with no trees (table 1).According to the analysis in table 2, 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. 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 also highly complement with the previous studies by (Nair, 2002, Dixon, 1995, Sharrow and Ismail, 2004) that suggested that plantation forest can conserve and sequester soil carbon due to high carbon input or exchange between the systems. They also indicated that a forestation of agricultural land use systems have the potential to offset immediate greenhouse gas emissions associated with deforestation and shifting cultivation.

## 3.2 Correlation analysis of soil properties

### 3.2.1 Correlation analysis between SOC and soil pH




Linear correlation (Pearson's test) was used to assess the relationship between SOC and soil pH. Based on the analysis, pH was significantly and negatively correlated with SOC at ($P<0.01$, $r = -0.032$) (figure 2). On the other hand, SOC (%) showed a decreasing trend along the soil profile while pH was increasing with the depth. This showed that increased in soil pH is due to lower in SOC content of the soil. Previous studies suggested that soil pH determine the microbial activities in the soil (M.J. Bell and F. Worrall 2009). According to this study, higher pH resulted in greater microbial activities that consequently increase organic matter mineralization or reduced in SOC. Increased soil acidity (lower pH) reduces the intrinsic activity of the microbial community (Kemmit *et al.*, 2006).

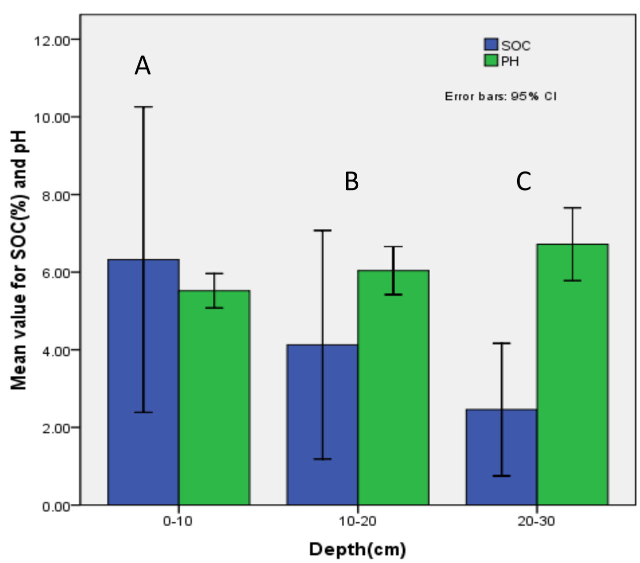



**Figure 2**

Relation between SOC and pH across soil depth

### 3.2.2. Correlation analysis between SOC and soil bulk density

Correlation analysis between SOC and soil bulk density showed that, bulk density negatively correlated (r= -0.878, P< 0.01) with SOC (figure 3).

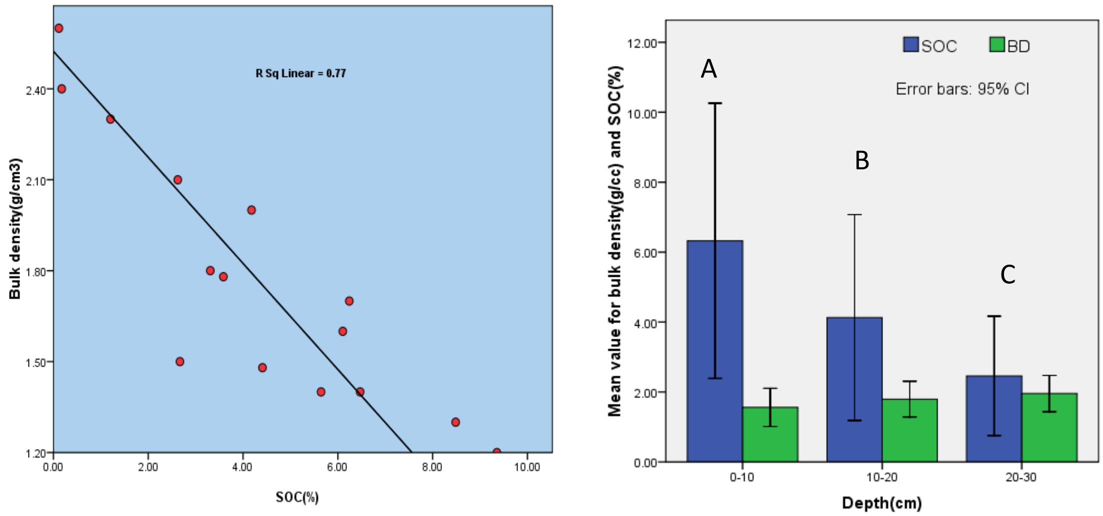



**Figure 3**

The linear regression analysis of soil organic carbon content (%) and bulk density (g/cm$^3$): (B) The relationship between SOC and bulk density along the soil profile

The previous studies also suggested that increased in soil bulk density decrease organic matter content and vice versa (Ekwue and Soane 1990). This was due to the fact that bulk density affects soil porosity, aggregate stability, size distribution, and soil particle density that are functions of soil organic matter (Baldock and Nelson, 2000). A decrease in organic matter would cause a decrease in porosity, thereby reducing soil infiltration, and water and air storage capacities (Celik, 2005).

### 3.2.3. Correlation analysis between SOC and soil moisture content

The correlation analysis in (figure 4) showed that, there is strong positive correlation (r=0.893, P< 0.01) between SOC and soil moisture content (figure 6). Different studies also suggested that soil organic matter increases water holding capacity of the soil through increasing the pore spaces between the soil particles. Similar observations were made by other authors (De Jong, 1983 and Kern, 1995). They investigated that increased in organic matter content meant higher water holding capacity of the soil. Increased soil moisture content can also reduce the amount of dissolved oxygen that could be important for the microbial activates or decomposition of soil organic matter (Breland and Hansen, 1996).

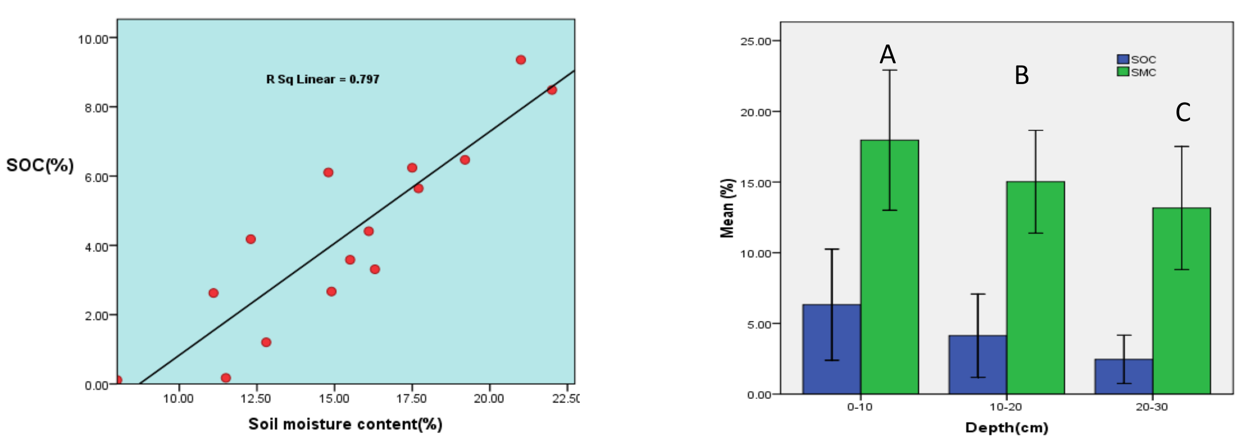



**Figure 4**

(A) The linear regression analysis of soil organic carbon content (%) and moisture content (%). (B) The relationship between SOC and moisture content along the soil profile.

## 4. CONCLUSION AND RECOMMENDATIONS

This study examined the effect of plantation forest to store soil organic carbon. It was identified that the integration of trees with grass is important to sequester more soil organic carbon as compared with mono cropping system. In order for countries to mitigate 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 are very important.

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