SOIL CARBON AND NITROGEN DYNAMICS IN A SILVOPASTURE AGROFORESTRY ECOSYSTEM IN NORTH ALABAMA

Christina T. Igono(M.S), Dr. Ermson Z. Nyakatawa(Ph.D) and Dr. David A. Mays

Department of Biological and Environmental Sciences, Alabama A&M University.

ABSTRACT

Agroforestry systems are used to manage, maintain and develop the ecosystem with the aim of achieving agricultural and economic growth which also helps in sustaining the environment. The study was done to assess environmental sustainability of silvopasture system by measuring the impact of forage production and management practices on indicators of soil quality, productivity and sustainability and also to investigate the effect of soil management practices on soil C and N sequestration and emission of CO_2 to the atmosphere. The study was conducted at the Winfred Thomas Agricultural Research Station, Hazel Green, Alabama in the Tennessee Valley Region of North Alabama in 2011 and 2012. A total of 13 treatments were used in a split-plot experimental design. Soil samples from the study area were analyzed for soil pH, total soil C and N. Data for soil moisture, soil temperature and soil CO_2 fluxes were collected in the field. Inorganic fertilizer application increased total soil N in the fertilized plots, by an average of 91% in the 0-90cm soil depth. Forest plantation plots had higher total soil N and C, compared to the agroforestry plots suggesting a higher potential for soil C and N sequestration in the densely planted system compared to the wider agroforestry planting. Soil CO_2 fluxes in the grass pasture system were consistently higher compared to those in the loblolly pine plots prior to grazing. The soil CO_2 fluxes were significant and highly correlated to the soil temperature in the silvopasture plots. Changes in total soil C due to soil management practices usually take time to be realized. It is therefore expected that with time, increased forage production and litter accumulation, due to fertilizer application, can increase soil C storage due to more biomass input.

PROBLEM STATEMENT

- Increased anthropogenic emissions of greenhouse gases (GHGs) such as carbon dioxide (CO_2) have been associated with global warming which is the cause of climate change.
- The concentration of CO_2 has increased by 31% from 280ppmv in 1850 to 380ppmv in 2005, and is presently increasing at 1.7ppmv yr-1 or 0.46% yr-1.
- Anthropogenic activities such as land-use change, deforestation, biomass burning, draining of wetlands, soil cultivation, and fossil fuel combustion are also contributory factors to increased atmospheric concentration of GHGs.

RESEARCH HYPOTHESIS

- To investigate the effect of soil management practices for forage production on soil C and N sequestration in a silvopasture agroforestry ecosystem.
- To evaluate the potential for environmental sustainability in a silvopasture agroforestry ecosystem.

OBJECTIVE

- Sustainable land use systems such as agroforestry can reduce soil emission of CO_2, and sequester C and N in the soil.
- Agroforestry system can in the long term, reduce atmospheric concentrations of CO_2 thereby contributing to climate change mitigation.

MATERIALS AND METHODS

Research Site

The study is conducted at the Winfred Thomas Agricultural Research Station, Hazel Green, Alabama (latitude 34º 89' N and longtitude 86º56' W), in the Tennessee Valley region of north Alabama.
The soil at the study site is a Decatur silt loam (fine, kaolinitic, thermic, Rhodic Paleudult). An existing loblolly pine agroforestry planting and loblolly pine plantation-density planting established at the Winfred Thomas Agricultural Research Station in 2007.

Data Collected

✓**Soil Sampling:** Soil was sampled using a tractor mounted soil probe (0-5, 5-15, 15-30, 30-60 and 60-90cm) depths respectively.

✓**Soil pH:** This was measured using an Acumet LX pH meter.

✓**Temperature:** Temperature was measured using the Mannix digital soil thermometers inserted in the 0-15cm soil profile.

✓**Moisture:** Soil moisture was measured using a Delta-T PR2 soil moisture probe (Delta-T Devices Ltd. Cambridge, England) attached to a Delta-HH2 readout unit (10, 20, 30, 40, 60 and 100cm depths).

✓**Soil CO_2 fluxes:** This was measured using the portable IRGA based LI-6400-09 (LI-COR., 1997, 1998) soil CO_2 flux measuring system (LI-COR Inc. Lincoln, NE).

✓**Soil Total C and N:** Total C and N was analyzed using the dry combustion (Dumas method), with LECO TruSpech CN analyzer.

Soil Sampling Using a tractor mounted soil probe, Summer 2011 and 2012.

Soil Moisture, Temperature and CO_2 Flux Measurement in a Fertilized plot

Table 3. ANOVA showing the soil pH, Total N and Total C content in clones (2011 and 2012)

Sources of variation	pH	Total N (%)	Total C (%)
Year	-------------------------- Pr > F	------------------------	
2011	0.8163 NS	0.0366*	0.0001***
2012	0.0474*	0.0270*	0.0007***

*, **, *** Significant at the 0.025, 0.05, 0.10 probability level respectively; Not significant(NS).

Conclusion

The results from this study used to investigate the baseline effects of soil management practices for forage production on soil C and N changes in a loblolly pine silvopasture agroforestry ecosystem suggest that, despite a slight increase in soil pH due to lime application in 2011, more time is needed to obtain significant changes in soil pH to the targeted values between 6-7for optimum forage production in the grazing plots.

The soil CO_2 fluxes were significantly and highly positively correlated to soil temperature in the silvopasture plots. Although, it was observed that high soil moisture was associated with higher CO_2 fluxes, the correlation between these variables were not significant.

These findings are however, preliminary as the study is still in its infancy. More time and samplings are needed before any solid conclusions can be drawn from this long-term study.

Soil pH

❖ The soil pH, which ranged from 4.64 to 5.37 was in the acidic range. Acidic pH is low in organic C and lacking water soluble basic cations such as Ca^{+2}, Mg^{+2} and K^{+}. And high in Aluminum, manganese and iron.

❖ Compared to baseline soil pH values of 2011, soil pH values in 2012 were slightly higher by an average of less than 1.00 unit.

❖ There were no significant differences in soil pH among the fertilized and non-fertilized plots in 2011. While in 2012, there were significant differences in soil pH among the treatments(Anova Table3)

Table 2. Total soil C content (%) in Silvopasture plots under no-fertilized (NF), fertilized (FF) and forest plots. 2011 and 2012

Soil Depth (cm)	Control Plot (NF)	Fertilizer Plot (FF)	Forest Plot	Control Plot (NF)	Fertilizer Plot (FF)	Forest Plot
		Baseline July 2011			July 2012	
	----------------------------	Total soil C (%)	----------------------------			
0-5	0.55 (0.03)	0.54 (0.03)	1.09 (0.48)	0.85 (0.15)	0.94 (0.18)	0.80 (0.17)
5-15	0.54 (0.02)	0.54 (0.02)	0.94 (0.15)	0.61 (0.08)	0.67 (0.11)	0.60 (0.09)
15-30	0.58 (0.10)	0.54 (0.03)	0.86 (0.15)	0.58 (0.05)	0.60 (0.05)	0.57 (0.03)
30-60	0.63 (0.20)	0.64 (0.21)	0.78 (0.14)	0.56 (0.03)	0.56 (0.02)	0.57 (0.02)
60-90	0.71 (0.21)	0.73 (0.26)	0.75 (0.13)	0.56 (0.02)	0.55 (0.02)	0.56 (0.02)
Mean	0.60a	0.60a	0.88b	0.63a	0.66a	0.62a

Standard errors of mean are in parentheses

Total Soil Carbon (TSC)

○ There were no significant differences in total soil carbon (TSC) concentration in the 0-90cm soil dept in the silvopasture plots due to fertilization or vegetation in 2012 (Table 1).

○ In 2011, TSC in the traditional forest plots in the 0-90cm soil depth which averaged 0.88% was 47% higher than that in the other plots.

○ Contents of SOC and total N are impacted by comprehensive factors including natural factors such as soil types, moisture, temperature, and anthropogenic factors such as fertilizing, farming, and management.

○ The content of TSC in 2011 and 2012 was highly significant (Anova Table).

RESULTS AND DISCUSSION

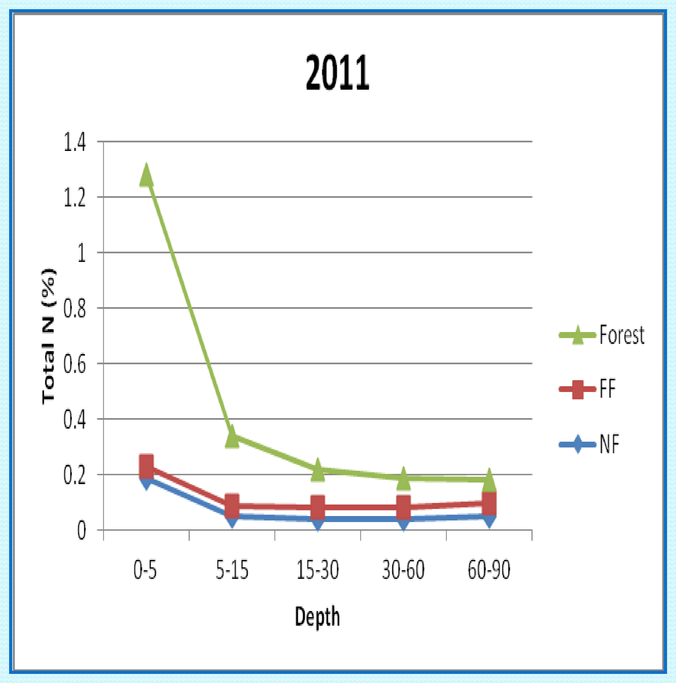

Figure 1. Total Soil N before the fertilizer application in 2011

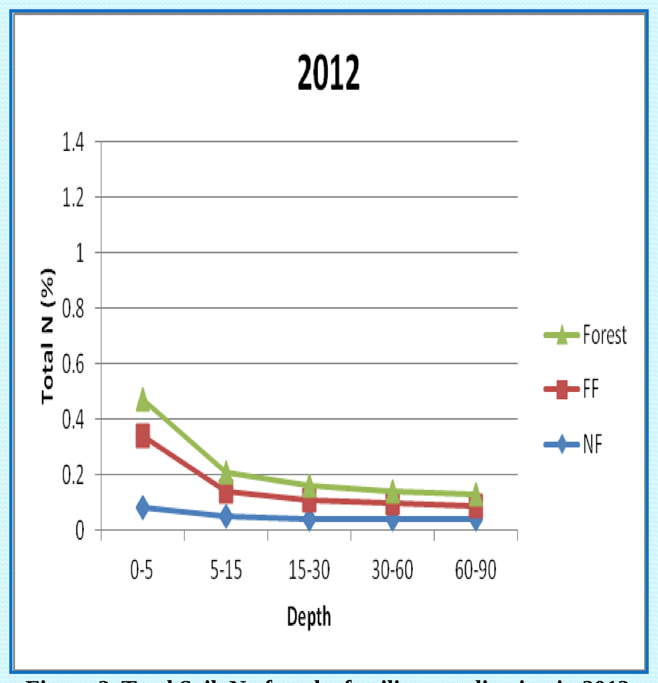

Figure 2. Total Soil N after the fertilizer application in 2012

Table 1. Soil pH in Silvopasture plots under no-fertilized (NF), fertilized(FF) and forest plots . 2011 and 2012.

Soil Depth (cm)	Control Plots (NF)	Fertilizer Plot (FF)	Forest Plots	Control Plots (NF)	Fertilizer Plots (FF)	Forest Plots
		Baseline July 2011			July 2012	
	----------------------------	Soil pH	----------------------------			
0-5	4.64 (0.56)	4.64 (0.38)	6.13 (0.43)	5.37 (0.40)	5.40 (0.39)	5.36 (0.27)
5-15	4.69 (0.63)	4.67 (0.51)	5.96 (0.38)	5.20 (0.76)	5.52 (0.42)	5.28 (0.28)
15-30	4.67 (0.67)	4.77 (0.32)	5.92 (0.37)	5.17 (0.48)	5.29 (0.41)	5.26 (0.23)
30-60	4.72 (0.55)	4.88 (0.51)	5.80 (0.38)	4.94 (0.67)	5.26 (0.70)	5.02 (0.42)
60-90	5.01 (0.54)	4.88 (0.80)	5.71 (0.42)	5.09 (0.59)	5.09 (0.63)	4.66 (0.78)
Mean	4.74a	4.77a	5.90b	5.15a	5.30a	5.13a

Standard errors of mean are in parentheses

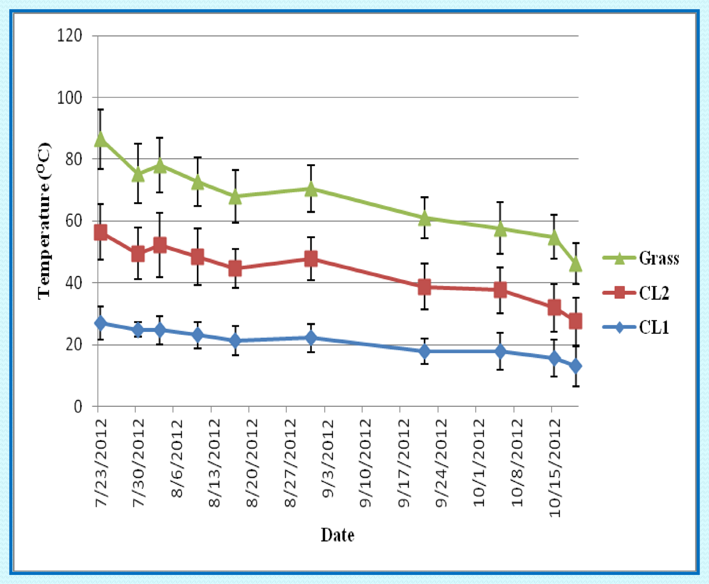

Figure 4. Soil temperature measured from Summer to Fall 2012

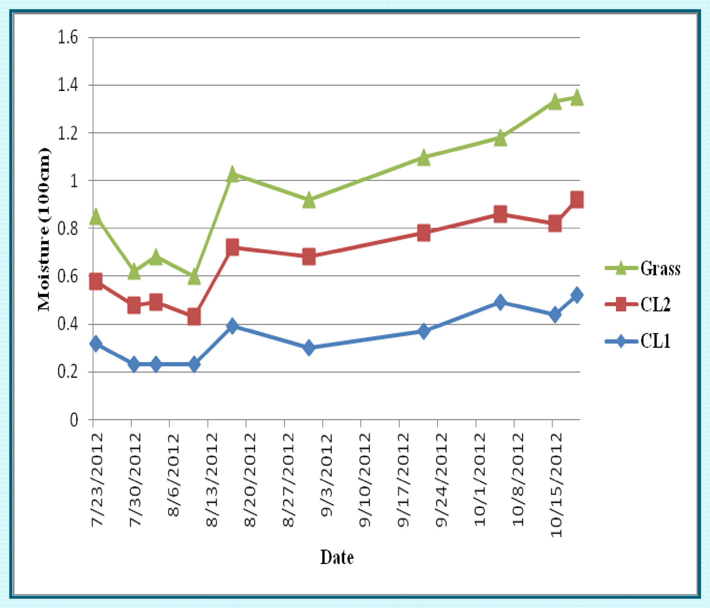

Figure 4. Soil moisture measured from Summer to Fall 2012

Total Soil Nitrogen(TSN)

- There were no differences in TSN content between the no-fertilized (NF) control plots and the fertilized (FF) plots at each soil depth in 2011 Figure 1.
- In 2012, TSN in the fertilized plots were 22.5% , 80%, 75%, 50%, and 25% higher compared to the unfertilized control plots in the 0-5cm, 5-15cm, 15-30cm, 30-60cm, and 60-90cm soil depths, respectively. Figure 2.
- Total soil N in the standard forest plots was significantly higher than that in the NF and FF plots in the 0-15 cm soil depth in 2011, whereas in 2012, TSN in the standard forest plots was higher than that in the unfertilized plots.
- The higher TSN in the forest plantation plots indicate a higher potential for soil C sequestration in the densely planted system compared to the wider agroforestry planting.
- There was significant difference in the TSN in 2011 and 2012 (Anova Table 3)

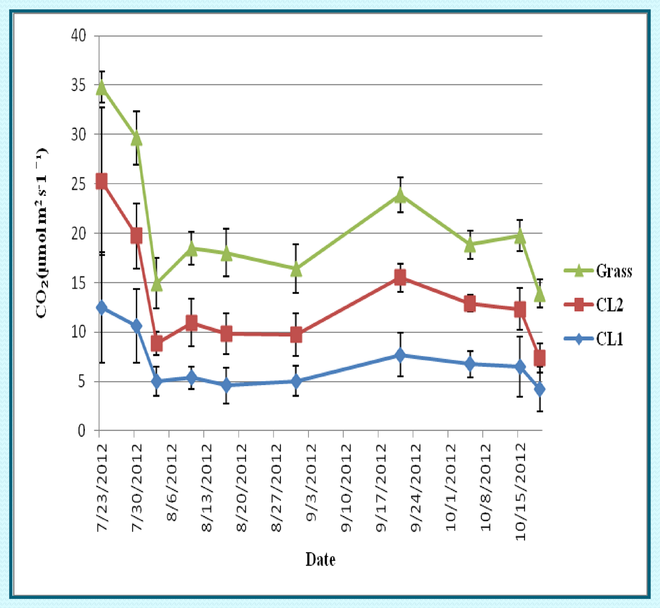

Figure 4. Soil CO_2 fluxes measured from Summer to Fall 2012

Correlations among CO_2 flux, temperature, moisture (30cm) and moisture (100cm) in depth

	Temperature (ºC)	Moisture_30 (cm)	Moisture_100 (cm)
	----------------------------	Clone 1	------------------------
CO_2 (µmol m^2 s^{-1} ⁻¹)	0.22982***	-0.01518 NS	-0.06983 NS
Temperature (ºC)		-0.05086 NS	-0.06488 NS

*, **, *** Significant at the 0.025, 0.05, 0.01 probability level respectively; NS- Not significant.

Soil Carbon dioxide (CO_2) Fluxes, Temperature and Moisture

✓ Soil CO_2 fluxes were significantly and highly positively correlated to soil temperature in the silvopasture plots ($r = 0.2298$; $p<0.0001$) and negatively correlated to soil moisture content ($r = -0.0698$, $p<0.1561$). A positive correlation between soil temperature and soil, basically means that CO_2 fluxes increase when temperature is high and it decreases when the temperature is low. The results from this study are in agreement with reports other scientist who also found weak correlations between CO_2 fluxes and soil water content.

✓ Results from many models have suggested that climatic warming will accelerate the release of carbon dioxide from soils, leading to additional warming. Temperature and water content are the factors most commonly related to temporal variation in CO_2 efflux from soil (Davidson et al., 2000).

✓ Amongst several other factors, agricultural management strategies have an effect on both the emission of CO_2 from soil and its sequestration capacity in soil. According to Ghoshal et al, (1995), such practices are of importance not only in terms of agricultural sustainability but also in issues related to climate change.

REFERENCES

Cox, P.M, Betts, R. A, Jones, C .D, Spall, S. A and Totterdell I. J. (2000). Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature 408. pp184–187.

Davidson, E, A., Verchot, L. V., Cattânio, J, H., Ilse L. Ackerman, I L and J.E.M. Carvalho J.E.M. (2000). Effects of soil water content on soil respiration in forests and cattle pastures of eastern Amazonia. January 2000, vol 48, Issue 1, pp 53-69.

Ghoshal, N., Singh, S and K.P. Singh (1995). Soil CO2 Flux From A Tropical Dryland Rice-Barley-Fallow Agroecosystem: Impact Of Application Of Soil Amendments With Varying Resource Quality. Department of Botany, Banaras Hindu University, Varanasi-221005, India

Lassoie, J.P. and Buck. L. E. (2000). Development of Agroforestry as an Integrated Land use Management strategy. pp. 1-29 IN H.E. Garrett, W.J. Rietveld, and R.F. Fisher (eds.) North American Agroforestry: An Integrated Science and Practice. American Soc. Agronomy, Madison, WI.

Rocheleau, D.E. (1999). Confronting complexity, dealing with difference: Social context, content, and practice in Agroforestry. pp. 191-244 IN L.E. Buck, J.P. Lassoie, and E.C.M. Fernandes (eds.). Agroforestry in Sustainable Agricultural Systems. CRC Press, Lewis Pub. Boca Raton, FL.