Physicochemical Properties of Bamboo (Arundinaria Alpine) Based Agroforestry Practice in Dawuro Zone, South West Ethiopia

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Abstract
On-farm trees are known to contribute to biophysical and economical sustainability at farm and landscape levels. This study assessed the contribution of woodlot Bamboo Agroforestry practice on some selected soil fertility parameters, the influence of bamboo woodlot Agroforestry on crop production and soil fertiliity at Dawruo zone, Southern Ethiopia. Soil samples were collected from under the canopies of five culms at five radial distances (0.5-1, 1.5-2, 2.5- 3, 3.5-4 and 10m) away from the trunk and a depth (0 – 30cm) for each radial distance. The soil samples were analyzed for physical and chemical properties. The soil textural class of the soil was sandy loam at all radial distances. There was no significant difference in the textural classes between samples taken from open field and under the canopy. Chemical properties including, available P and soil pH had the same tendency with radial distances from the tree trunk. But organic carbon and Total N decreased with increased of distance from the tree base and there is significantly differ between Total N ($p< 0.05$). On the hand, the farmers' perception that bamboo culms depletes soil nutrient was not supported by soil analyzed. In conclusion, bamboo based Agroforestry practice influence soil nutrients at Ultisols in research site do not influence fertility of soil under their canopy. Indeed, the tree can be regarded as agroforestry trees to integrate them with crop production to enhance the sustainability of soil fertility.
Keywords: Bamboo, Agroforestry, Soil fertility, Crop land

1. Introduction

Bamboo is fast growing species and therefore, known as "Green Gold". This green gold is sufficiently cheap and plentiful to meet the vast needs of human populace from the "*child cradle to the dead man's bier*" that is why sometimes known as "*poor man's timber*." (Nirmal, 2010). Technically, bamboos are grasses belonging to the subfamily *Bambusoideae* under the family of *Gramineae*. 90 genera and 1500 species of which only about 50 species are domesticated so far (FAO, 2005).

There is a serious concern in Africa about climatic change, soil erosion and large-scale desertification. There are different approach to reduce these problems, One approach for reducing the pressure on the timber species is by developing and establishing plantations, processing industries (small and large) and markets for Non-Timber Forest Products such as Bamboo (Kwaku, 2006).

Africa holds about 40 bamboo species, of which two are indigenous to Ethiopia: the African Alpine Bamboo (*Yushane alpine* K. Shumann Lin; synonym: *Arundinaria alpina* K. Schumann) and the monotypic genus lowland bamboo *Oxytenanthera abyssinica* (A. Richard) Munro(Kassahun, 2000).These species are also found in some other African countries, but nowhere else outside the African continent. They are indigenous to Ethiopia and endemic to Africa, confined to the sub-Saharan region. Africa has 1,500,000 ha of which, Ethiopia has about 1 mill. ha of high- and lowland bamboos, the latter being more dominant (850 000 ha). Thus, 67% of African bamboo resources and more than 7% of the world total are found in Ethiopia (Kassahun, 2000).

Bamboo forests have ecological and environmental functions in term of soil erosion control, land rehabilitation, water conservation and carbon sequestration. The rapid increase in the rate of deforestation makes bamboo an ideal investment or choice for plantation. Biological characteristics and growth habits of bamboo make it more important in solving the problem of degraded lands, like for erosion control and carbon sequestration (Zhihua, 2013).

Boundary planting with bamboo is a common land-use system in Ethiopia. Farmers dwelling in well to moderately drained soils adopt the innovation, mainly to earn cash. The practice, evolved through generations, now nearing a climax with a gradually increasing demand for bamboo products. Farmers mainly employ indigenous knowledge in promoting bamboo planting and fine tune the processing of bamboo stems in to different products. Distant households sell bamboo stems to those nearby main roads for processing mainly in to mats (Azene, 2007).

Bamboo planting in the wet high land of Ethiopia is confined to farm boundaries, on fence rows between crop land and grazing lands, along farm plots. It casts shade on adjacent crops and rainwater accumulate on the canopy and drops in big droplets; these combined effects reduce crop growth and the yield up to 2m distance from the bamboo line. Root competition is less serious and causes little impact on crop yields since lateral root extension is limited. Such crops as barely and potato, as well thatching grass are commonly grown adjacent to bamboo liens (Azene, 2007).

Bamboo forests are important forest type in subtropical and tropical region in the world. Due to its biological characteristic and growth habits, bamboos are not only an ideal economic investment that can be utilized in many different manners but also has enormous potential for eco-restoration of degraded lands. Bamboos are one of those communities which rapidly colonized disturbed lands due to their adaptability and nutrient conservation ability. According to Zhihua (2013) Bamboo protects steep slopes, soils, and water ways, prevents soil erosion, sequesters carbon and brings many other ecosystem benefits. Bamboo forest survey by GTZ (1997) in SNNPRS confirmed that the natural stand of *Arundinaria alpina* was over 20,000 ha in Masha Andiracha forest alone. There are also abundant wood lots of bamboo in Sidama, Gedeo ,Gamo-Gofa and Dawruo zones.

Likewise, Dawruo is one of the intervention regions of the current bamboo project. It is located in the heart of the "bamboo land" in the southern highlands; it constitutes a crucial important national asset of inestimable value. It is inhabited by a majority of the area's population; and boasts of other major human and natural resources, such as bamboo resources. Bamboo Agroforestry practices of Dawruo can be described as farm -based. The farm-based practices comprise planting trees on and around agriculture fields and Bamboo wood lots. Agriculture is the main source of livelihoods of the area. Moreover, Bamboo Culms on farmland form an integral part of the farming system. Here, bamboo is an important part of the farming systems that are based on the cultivation of Enset and a wide range of vegetables as well as the production of milk for cash incomes (Berhanu *et al*., 2007). However, Agricultural land expansion affects the bamboo forests of Dawruo zone. This resource has great contribution in improving the livelihood, tackling food insecurity problem, decreasing pressure on natural forest, reduce erosion hazard and has great social values. However, lack of awareness about its multiple use, lack of technical information particularly on the local bamboo resource management, lack of network and information gaps between various stakeholders of the sector, and the over exploitation of the resources are the main challenges facing bamboo resources in the study site. Moreover, the depletion of forest resources and increasing demand for forest products and services especially of the rural people who depend on forests for livelihoods have widened the gap between the demand and supply of forest products and services. Finding alternative options to increase the supply of forest products and services to support rural livelihoods have become a fundamental concern. Even though different research conducted related with bamboo, no quantitative information on the extent of bamboo plantation influence on the soil has been conducted in the study area. Therefore, the study was aimed bamboo based Agroforestry practice influence on selected physiochemical properties of the soil at Dawruo Zone. It provides insights on the contribution of agroforestry to the livelihoods of large and marginal households. It will also provide information on Urgent and effective action required to secure the future existence of bamboo agroforestry systems and for its use in systems managed on a sustainable basis, the information generated form the findings may give some guidelines for implementation of some agroforestry practices in similar areas. The same applies to the formulation of strategies for dealing with intensifying production from existing bamboo forests, expanding bamboo production to private farms, and improving and diversifying utilization of bamboo resources. It becomes therefore logical and imperative that the formulation of any development strategy be devised to reflect these local differences and technical management problems Understanding, scientifically, the influence of these culms will also help to focus efforts in developing suitable management and future research directions.

2. Material and Methodology

2.1. Descriptions of study area

The study was conducted at Dawuro Zone, Southern Nation National and People's Regional State (SNNPRS), Ethiopia. The rain fall in the study area is bimodal, with the main rainy season from July to October and short rainy seasons from March to May. Mean annual rainfall amounts to 1400mm. temperature vary between 15^0c and 32^0c.The Zone have total population of 0.586 million out of this more than 90% is living in rural areas. The livelihood of the majority of the population depends on agricultural activities.

2.2. Data to be collected

2.2.1. Experimental design

Farmers having bamboo culms of the same age were identified and five sample culms selected. Sample culms were selected based on their similarity in terms of age, diameter at breast height, height, and crown diameter. The selected culms were: (1) absence of influence from domestic animals and other trees; (2) presence of relatively homogenous site conditions; (3) growth vigor of the culms. Each culms group was considered as a replicate and the area covered by the canopy divided into five radial transects. five plots of 0.5 x 0.5 m will be established on each radial transect at distances of 0.5-1, 1.5-2, 2.5-3, 3.5-4 and 10m away from the tree trunk and depth (0-30cm from the surface). The experimental design was laid out by a factorial arrangement of randomized completely with five replications.

2.2.3 Soil sampling and analyses

Random soil samples were collected from under the canopies of five culms groups at five radial distances away from the trunk and a depth (0 – 30cm) from the surface. The 10m distance represented sampling point, which was assumed to be free from tree influence, and thus used as control. The soil sample at each sampling spots at the depth was collected from the four compass directions. Soil samples taken from the same spot distances in the five radial directions were combined to make composite samples. Thus, a total of 25 (5 distance x 5 culms x 1 depth) soil samples were collected and analyzed. The soil samples were air-dried and ground to pass 2 and 0.5mm (for total nitrogen and OC) sieves.

All samples were analyzed following Standard Laboratory Procedures (Sahlemedhin Sertus and Taye Bekele, 2002). Organic carbon and total nitrogen contents of the soil were determined following the wet combustion method of the Walkley and Black method, and wet digestion procedure of Kjeldhal method, respectively (Van, 1992). Available P was extracted by Olsen method (Olsen *et al.,* 1954). The pH (1:2.5, soil: water) of the soil was measured in water using pH meter with glass-calomel combination electrode (Thomas, 1996). Soil texture was determined by using Bouyoucos Hydrometer method.

2.2.4 Statistical Analysis

The All data were analyzed by general linear model (PROC GLM) function of SAS (SAS, 1997). A combined analysis of variance (ANOVA) was carried for the parameters studied; test at probability levels of 5 % was used to compare means.

3. Result and Discussion

3.1 Physicochemical Properties of Soil as Influence by Tree Canopy

The present study revealed that the textural classes of the soils were clay loam at both location in 0-30 cm depth and there was no significant difference between samples taken from open field and under the canopy (Table 3). Physiochemical properties of soil were significantly better in the bamboo forests (Zhang, 2010). This is consistent with that of Kamara and Haqee (1992) who indicated that similar textural class under the *Faidherbia albida* tree canopy. Tadesse et al. (2000) and Zebene Asfaw (2003) revealed that the textural class of the soil under the *Millettia ferrugine* and *Cordia africana* trees canopies in Ethiopia. Similarly, in a comparative study, Pant *et al*., (1993) observed that the presence of bamboo in the forest significantly affected the physical and chemical properties of soil. He also reported that the soil with bamboo was found to show higher pH compared to the soil without bamboo. Moreover, bamboo plays an important role in maintaining and improving the nutrient status of the soil.

Table 1: Influences of bamboo culms on some selected Physicochemical Properties of soils

Bamboo *culms*					
Selected Physicochemical Properties of soils					
Distance from the tree base (M)	Soil pH	AV.P (mg kg^{-1})	OC %	TN %	Textural class
0.5 – 1	5.34	0.89	2.04	0.17	Sandy loam
1.5 – 2	5.20	1.00	1.92	0.17	Sandy loam
2.5 – 3	5.36	0.93	1.66	0.14	Clay loam
3.5 – 4	5.34	1.11	1.56	0.13	Sandy loam
10	5.24	1.00	1.36	0.13	Sandy loam
$LSD_{0.05}$	0.19	0.77	0.70	0.045	
CV	2.76	57.95	30.68	27.92	

Values followed by the same letters within a row are not significantly different at P=0.05

The pH (H_2O) value of the samples taken from surface layer was strongly acidic. According to Herrera (2005) classification and there was no significant difference between the controls (Table 1). Based on this classification, the pH of the soil was strongly acidic in and out of the canopy, which is not satisfactory for growth of most crops (Havlin *et al.,* 1999).

The OC values were within the range of moderate to high according to Herrera (2005) who classified OC as low (0.6-1.16%), moderate (1.16-1.74%) and high (>1.74%). Organic carbon content decreases with increasing distance from tree trunk. The result was in line with that of Tisdale et al. (1993) who indicated that top soils are characterized by accumulation of humified organic matter, while deeper sub soils are poor in organic matter content, which also decreased with depth, and this was in agreement with Sahlemedhin Sertus (1999) who reported that OC was tied to humus content of soil and their value decrease with the decrease in OC. In addition, slightly higher clay content with depth, might have also contributed to the decrease in OC. Moreover, Yiping *et al*. (2010) found that bamboo forests are likely to sequester carbon at a similar level to fast-growing trees and, hence, significantly contribute to the efforts being made to mitigate climate change and also similar research result showed that types (varying from 122 t C/ha to 263 t C/ha). The quantity of carbon sequester by any forest type can be extremely influenced by diverse factors like climatic and soil. However, it can be realized that bamboo will sequester prominent amount of carbon, if managed sustainably (Gaurav *et al., 2014).*

The TN contents of the soils were ranged from 0.13 to 0.17% the depths 0-30cm (Table 3). Which could be classified as low to medium according to Havlin *et al*. (1999) who categorized TN rate as very low (<0.1), low (0.1-0.15) medium (0.15-0.25), and high (>0.25). The low concentration of TN could be due to the effect of intensive and continuous cultivation of field that release N from organic matter decomposition. Total N decreased with increased of distance from the tree base and there is significantly differ between them ($p< 0.05$).

Available P content could be classified as high according to Herrera (2005) who categorized as very low (<3), low (4-7), medium (8-11), and high (>12). The Av.P content decreased with increased radial distance from tree trunk. The lower content of Av.P under canopy is attributed low accumulation of organic matter. Though, the concentration of available phosphorus in the canopies of both distances higher than that of the open areas, thus, the contribution of the trees to available phosphorus was very low and insignificant. These might be attributed to total phosphorus in soils is held organically combined forms with low amount of organic-P held by the active microbial biomass , the presence of Al and Fe in ultisols and alfisols might have brought P-fixation in such type of soils. Hence the recycling of P from organic materials may not be sufficient to the P requirement of crops. Sustained crop production with agroforestry on P deficient soils will typically require additional P inputs by crops (Buresh and Tian, 1997).

Bamboos have the potential to be incorporated into agroforestry systems in the tropics in place of conventional tree species due to their adaptability and diverse range of raw and manufactured goods which they produce(Purdew,2008; Nath *et al*., 2009). Most bamboo species are suitable agro-forestry plants. In China, agroforestry systems have very successfully combined bamboo species with tea, as well as with crops, such as watermelon, soybeans, sweet potatoes, sugar cane and vegetables, with fish pond management, and with production of edible fungi and medicinal plants (Jinhe, 2000). However, some species may out-compete the field crops or other tree crops grown in association. So, nutrient availability is the most important soil chemical properties governing growth and yield of bamboo. The content of available nutrients in the soil is positively related to yield and explain much of variation in yield across bamboo sites and regions in. Hence, bamboo growth and biomass is positively related to soil organic matter, which is the primary source of nutrients in bamboo cultivation sites in Korea. Nutrient availability depends not only on the inherent fertility of soil but also on whether bamboo stands are harvested, cultivated, and/or nutrients are applied externally (Kleinhenz and Midmore, 2001). Nitrogen is the element most required by bamboo, followed by potassium and phosphate. Litter decomposition in the root zone of the bamboo groves constitutes an important component in the existing ecosystem and is the major pathway for supplying energy and nutrient to the soil.

However, inter-specific competition in bamboo-based agroforestry system can be overcome by planting crop 8-9m away from the bamboo clumps (Nath *et al.*, 2009). Trenching (30-40 cm wide and 50-60 cm deep at 5-6m away from the clumps) to spatially isolate bamboo roots from the rest of the crops is recommended, if crops are to be planted at shorter distances (Nath *et al.*, 2009). The impact of bamboo growth on the soil may differ at species level. It is expected to increase the microbial biomass, particularly, in the rhizosphere zone by providing a larger root surface area that would help in enriching soil fertility by acting as a 'sink' and 'source' of the available plant nutrients (Singh *et al.,* 1997).

Bamboo planted on river banks to protect against erosion during floods, is a nutritious food source for local consumption, and provides a major source of revenue when exported in processed form, as in China (Anand *et al*., 1999; Arunachalam *et al*., 2002; Nadia *et al*., 2003; Hui Chaomao *et al*., 2006; Purdew, 2008) they are often used as a windbreak to protect cash crops that are more likely to succumb to strong winds (Andrew, 2010).

Boundary plantings of bamboo increase tree cover, fuelwood supplies and infiltration of rain, provide protection against wind, and reduce runoff (Muthuri *et al.,* 2005). Bamboo provides ecosystem services (Zhou *et al*., 2005; Ombir, 2008) such as carbon sequestration, erosion control, integrity of watershed hydrology, and local climate regulation (Midmore, 2009). The bamboo plant is an eminent means to start up reforestation, and often has a positive effect on groundwater level and soil improvement through the nutrients in the plant debris (INBAR, 2009). The rhizomes and roots grow in all directions forming a complex network of up to more than 1 m depth belowground, which effectively holds soil particles together, thereby, preventing soil erosion and promoting water percolation (Kassahun, 2000; Arun *et al.*, 2008; Nirmal *et al.*, 2010).

Bamboo plays a key role in restoring soil fertility through the accumulation of organic matter and nutrients during the fallow period. Litter on the soil surface is resistant to decay due to its structure and high silica content, preventing nutrient leaching and accumulating additional carbon in litter and soil organic matter (Kassahun, 2005).

Bamboo-based land-use systems in rural landscape sequester CO2 through the carbon stored in their biomass (Zhou *et al.*, 2005; Arun *et al.*, 2008). It absorbs from the air 12 metric tons of harmful carbon dioxide per hectare, which is twice that of a similar size, forest, and produces 35-46.2 per cent more beneficial oxygen than most plants (Ombir, 2008). Hence, it is the best plant to counter urban and industrial pollution. Recent research has shown that managed bamboo stands can sequester higher amounts of CO2 than natural bamboo forests and plantations of comparable fast growing tree species (FAO, 2007; INBAR, 2009). Bamboo produces more biomass when managed intensively, and modeling suggests that managed bamboo will sequester more carbon than fast growing tree species such as Chinese Fir and *Eucalyptus* (INBAR, 2009).

4. CONCLUSION

Agro forestry tree mixed with crop could increase agriculture production and productivity in area like Dawuro zone, where there is high population pressure and low soil fertility. To this end, bamboo could be one of the woodlots agro forestry practices. However, tree management practice and effect on soil and crop yield was not studied in the area. Thus, the research work was initiated, to evaluate influence of bamboo tree on some selected physicochemical properties of the soil Dawruo zone, Southern Ethiopia. Farmers have accumulated a vast local knowledge in managing agroforestry practices, which has been gain by experience and transferred from generation to generation. The overall results of chemical properties in this study, demonstrated that most soil parameters were no significant difference under the bamboo tree canopies as compared to the adjacent open areas. The influence on soil fertility is also more prominent in the surface soil close to the tree base than away from the tree truck, which trees enhanced soil fertility under their canopies are assumed nutrient recycling through litter fall and root turnover. Soil fertility management practices should be taken into consideration means to increase local knowledge on tree management practices using locally available resources. Based on finding of this study the following recommendations were made, Further longer term research on the biophysical, socio-cultural and economic are vital, to enhance the management practices, productivity and sustainability of parkland agro forestry practices, It is crucial to amalgamate indigenous and scientific knowledge in employing different agro forestry technologies for promoting and sustaining the overall productivity of woodlot agroforestry practices, Thus, further research is needed to clarify fully and to study, on the effect of bamboo tree on soil parameters and maize yield is needed for larger area and continuous data collection.

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