Original Research Article

Correlations between Tree/Shrub Diversity and Herbaceous Biomass with Soil Physico-Chemical Properties under *Acacia saligna* Canopy

Abstract

The present study was conducted to assess the correlation between woody species diversity, herbaceous cover and biomass with some soil physico-chemical properties under the canopy of A. saligna tree in semi-arid conditions of northern Ethiopia.As a tropical nation, Ethiopia has seen the majority of its native woody species regenerated or initiated, primarily through the integration of exotic species, in an effort to restore degraded areas. The study is conducted in Atsbi-Womberta district, in the Eastern zone of Tigray, Ethiopia.Twelve exotic A.saligna tree stands are selected with almost similar crown diameter, diameter at breast height, height and ages. Each A.saligna tree stands was considered as a replication.In this study, woody species richness was found significant positive correlation with the K. Similarly, other studies showed that some kind of relationships between woody species richness and soil nutrient availability such as soil fertility index and soil Ca, P and K contents. This study suggests that woody species density can progress markedly reduce the herbaceous biomass, because the more density plant community components was either severely reduced or completely absent of herbaceous species, such effect could become increasingly important at high tree densities.The positive and negative significant relation and similarly the positive and negative non-significant relation between some soil physicochemical properties and woody species diversity might be due to the species characteristics and soil nutrient availability of the site. Further study should be needed on soil seed bank, seed physiology and A.saligna canopy management options to fill the gap of the study under Acacia saligna canopy.

Keywords: soil fertility index, saligna canopy, soil nutrient availability, seed physiology

1. Introduction

Establishing quickly growing exotic tree species in tropically degraded land is a good way to increase biomass productivity per unit area and, as well as to catalyze the succession of native woody species in the understory (Brockerhoff et al., 2008). As a tropical nation, Ethiopia has seen the majority of its native woody species regenerated or initiated, primarily through the integration of exotic species, in an effort to restore degraded areas (Aubin et al., 2008; Alem & Woldemariam, 2009).Even though plantations of exotic species have played a crucial role for environmental rehabilitation, they are also widely viewed in a negative light in relation to native woody species diversity(Carnus *et al*., 2003).

Acacia saligna (Labill.) Wendl. (A. cyanophylla Lindley) is originated from South Western Australia (Pedley, 1986), which is considered as an exotic tree species in many parts of the world and an invasive species to some countries (Holmes & Cowling, 1997). One of Ethiopia's exotic tree species, *Acacia saligna (A.saligna)*, was brought to the Tigray region of Ethiopia in 1972 with the intention of restoring the ecosystem and conserving soil and water (Rinaudo and Admasu, 2010).It is an evergreen tree/shrub species that is grown in a variety of agro-ecological zones (Shumuye and Yayneshet 2011).According to Orwa et al. (2009), *A. saligna* grows quickly and may thrive in a variety of unfavorable environmental situations, including places that are prone to drought, waterlogged areas, and soil dominated by alkaline or saline.

A.saligna is one of the species from the genus of *Acacia* that spreads outside of their original range and they establish easily in new areas which threats the natural ecosystem functions by reducing the native biodiversity (Odat*et al*.,2011).Similarly described by Van Wilgen and Richardson (2012)large-scale plantation of alien species like*A.saligna species* in open areas have a negative impact on the regeneration potential and diversity of native woody vegetation, such as reducing species richness of native plants, disturbing nutrient cycling and altering the structure of the vegetation in adjacent native areas.

A. saligna tree plantation was practiced in the Tigray region in 1972 to restore degraded areas of the region (Rinaudo and Admasu, 2010). Although *A. saligna* is commonly grown in different parts of the region, butthe relationshipbetween woody species diversity, herbaceous biomass with some soil physico-chemical properties under its canopy has been not studiedyet for the semi-arid degraded ecosystem. Therefore, the present study was conducted to assess the correlation between woody species diversity, herbaceous cover and biomass with some soil physico-chemical properties under the canopy of *A. saligna* treein semi-arid conditions of northern Ethiopia.

1. **MATERIALS AND METHODS**

2.1 Study area

The study isconducted in Atsbi-Womberta district, in the Eastern zone of Tigray, Ethiopia.The district is geographically bounded between 13º 36"North latitude and 39º 36``East longitude .The district has an altitudinal variation ranging from 988 to 3063 m a.s.l.Barka Adisebha is the particular study area,and geographically,it is situated between 39° 39'30"-39°47'0" East longitude and 13° 45'30"- 13° 51'30" North latitude and has an altitudinal range of 2171 to 2718 m a.s.l. with two agro-ecological zones (5.5% midland and (94.5%) highland (Figure 1).

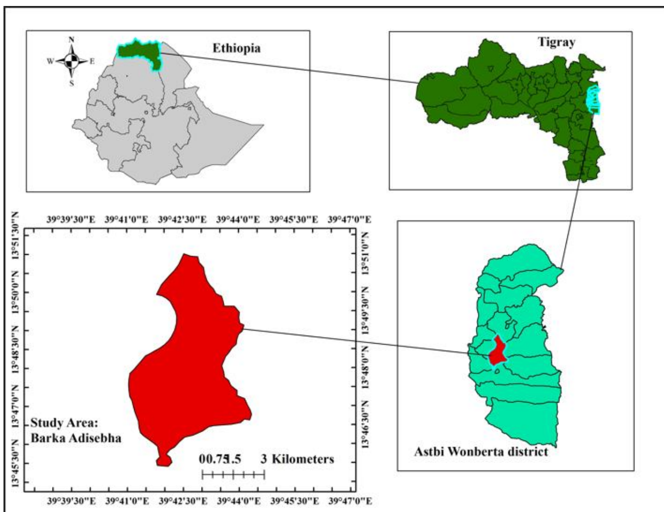

Figure 1; Map of the study area

The consecutive eleven years (2006–2016) of the average monthly rainfall of Atsbi-Wemberta district was 613 mm, while the mean monthly temperature of the district varies from 6.4-22.8°C (Figure 2).The detailed information regarding on the long term (11years) mean monthly temperature and rainfall of Atsbi-wenberta district is depicted (Figure 2).

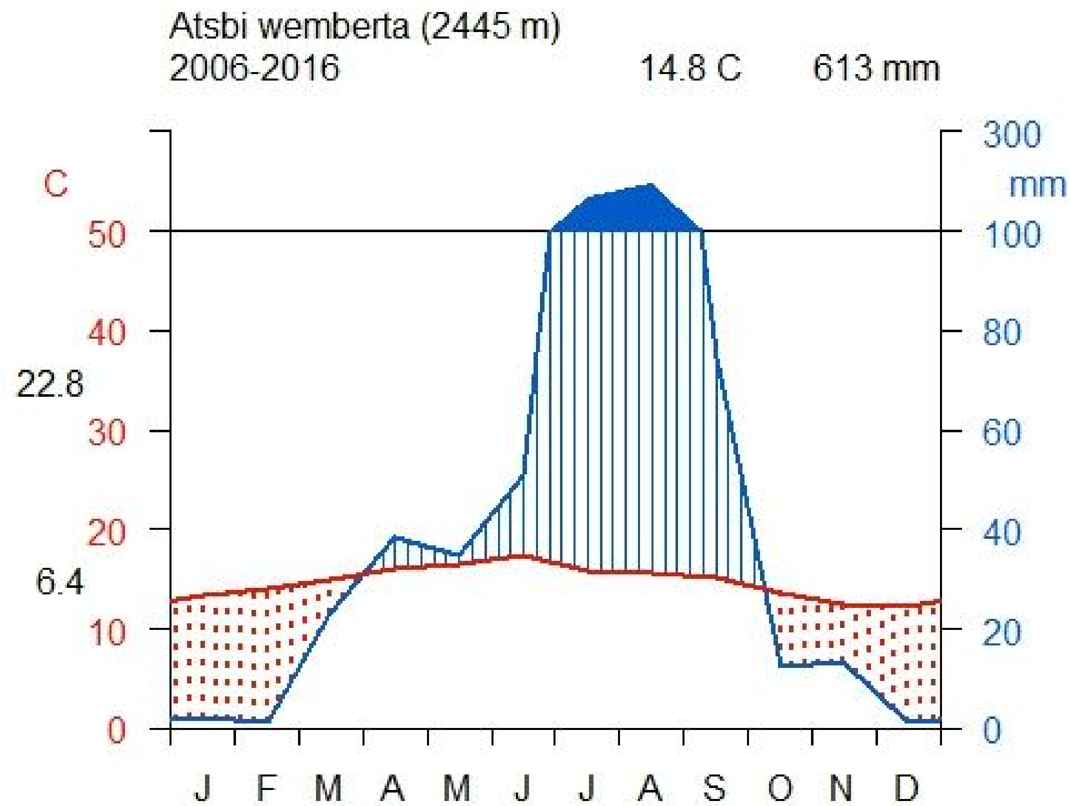

Figure 2;Walter -Lieth climatic diagram for Atsbi wemberta district (Source; Tigray Regional Meteorological service center).

1.2.Sampling design and data collection

Twelveexotic *A.saligna* tree stands areselected with almost similar crown diameter, diameter at breast height, height and ages. Each *A.saligna* tree stands was considered as a replication.The quadrates with a size 1 m^2 were visually placed under*A.saligna* tree stand, in which the sampling points were taken along the four directions under *A.saligna*canopy at a distance of 1 m away from the trunk. Briefly, the identification of all woody plants and the total number, as well as the height and dsh of individual seedlings and saplings of each species, were recorded. Individual woody categorizations were made as height <0.5 m and dsh < 2.5 for seedlings, h >0.5 m and dbh <5 cm for saplings (Birhane et al. 2007).

The nested quadrate plot design was employed to sample the herbaceous biomass production. Accordingly, the sub plots with the size of 0.5 m x 0.5 m were established at the center of each main plot. In each sub plots destructive method was used to quantify the herbaceous biomass production. The harvested fresh herbaceous biomasses were weighted in each quadrats and sub sample from the fresh herbaceous biomass were oven dried at 65 ^{0}c for 24 hours and weighted again to determine the herbaceous biomass production.

The soil samples were taken from under canopy of *A.saligna*using an auger at fixed 20-30cm soil depth (Mureithi et al. 2014; Tizita 2016), and finally sub samples were pooled to obtain one composite soil sample. The soil samples were air-dried at room temperature of 19-21□C, crushed, homogenized and passed through 2 mm sieve and subjected to analysis for soil texture, gravimetric moisture content, soil pH, soil organic carbon, available phosphorus, total nitrogen, exchangeable base (sodium, calcium, potassium and Magnesium), available potassium, electrical conductivity, and cation exchange capacity and further sieved through 0.5 mm size for analysis of soil total nitrogen. In addition, 20 soil samples were taken for analysis of soil bulk density using a core sampler of 5 cm height and 3 cm in diameter at soil depth 0-10 cm. The collected soil samples were analyzed in Tigray Agricultural Research Institute (TARI), Mekelle Soil Research.

2. Data analysis

Shannon diversity, Margalef (Richness), Simpson (dominance) and Equitability (evenness) were calculated using Paleontological STatistics (PAST) software version 1.93.

The assumption of normality data on species diversity and herbaceous biomass were checked using the Shapiro – Wilk test. The correlation between soil physicochemical parameters and indigenous woody species diversity indexes was tested using the matrix Pearson correlation methodsusing SPSS for windows version 20.

3. RESULTS AND DISCUSSIONS

3.1. Correlation between some soil physicochemical parameters and woody species diversity indexes

Shannon diversity indexes were insignificant positively correlated with pH, SOC, Av.P, Av.K, (P>0.05), and negatively insignificant correlated with TN (P>0.05, Table 1). The indigenous species richness was insignificant positively correlated with pH and Av.P and negatively insignificant correlated with SOC and TN (Table 1), whereas Av.K has a significant positive correlation with the species richness (Table 1). The Pearson's Correlation matrix showed that, Simpson_D diversity index has insignificant positive relation with pH, SOC, Av.P, Av.K, Av.K and TN, similarly the indigenous species evenness have insignificant positive relation with SOC, Av.P, Av.K, Av.K , TN and negatively insignificant with pH(Table 1). However, sand and silt was negatively and positively correlated with pH, SOC, Av.P, Av.K, Av.K and TN respectively, and clay was positively insignificant relation with pH, SOC, Av.P, Av.K and Av.K and negatively correlated with TN (Table 1).

Table 1; Pearson's correlations between soil physicochemical parameters and indigenous woody species diversity indexes**.**

	pH	SOC	Av.P	Av.K	TN	Sand	Silt	Clay
Species richness								
R	0.163	-0.09	0.182	0.298*	-0.176	-0.304*	0.290	0.210
P	0.267	0.54	0.215	0.04	0.23	0.036	0.045	0.151
Simpson_D								
R	0.03	0.170	0.274	0.142	0.056	-0.261	0.315*	0.068
P	0.839	0.248	0.059	0.335	0.704	0.074	0.029	0.646
Shannon								
R	0.123	0.042	0.189	0.239	-0.012	-0.163	0.175	0.08
P	0.406	0.776	0.198	0.101	0.935	0.268	0.233	0.589
Equitability								
R	-0.079	0.243	0.257	0.045	0.149	-0.165	0.249	-0.042
P	0.593	0.096	0.078	0.764	0.313	0.264	0.088	0.77

R: Pearson's coefficient of correlation; P: significance; *P<0.05

In this study, woody species richness was found significant positive correlation with the K. Similarly, other studies showed that some kind of relationships between woody species richness and soil nutrient availability such as soil fertility index and soil Ca, P and K contents (Pausas&Austin2001). On the contrary, many researchers reported that species richness decreases at higher soil fertility (Mittelbach et al.2001).That difference in pattern between woody species richness and some soil factors may be caused by the different type of species found at different agro ecology zones of the world.

Species richness was not correlated with total N. This result in lines with Nadeau and Sullivan(2015) that tree species richness was not correlated to Mg, Fe, Cu, Zn, and Mn contents, C/N ratio, and total N. However, this is also in contrary with the findings of Kumar et al. (2010) who found that total N was highly positively related to tree species richness. This difference might be generated due to the difference annual rain fall available and the rainfall itself affects the availability of nutrient cycling.

The soil pH showed several insignificant positive correlations with species richness, Simpson and Shannon diversity index, and insignificant negatively correlated with equitability. This result disagrees with Rodríguez-Loinaz et al. (2008) higher species diversity was observed at high pH value. The reason for the low correlation of woody species diversity and soil pH might be due to the negative effect of soil pH for the important nutrients. Similar result was reported by Acosta-Martinez and Tabatabai (2000) that soil pH negatively affected the availability of essential nutrients like: N and P.

On this study, the Av.P was positively insignificant with species richness and diversity. This might be due to the available of optimum soil nutrients for providing plant nutrition and their distribution. This is similarly reported by Janssens et al. (1998) highest number of species in grasslands was recorded below the optimum soil phosphorus level and at the optimum soil potassium level; beyond this optimum, species richness decreased.

3.2. Correlation between some woody species parameters and herbaceous biomass

Woody species density and Shannon diversity were negatively and positively correlated with herbaceous biomass respectively ($p<0.05$) (Table 2).However, species richness shows non-significant correlation with herbaceous biomass (Table 2).

Table 2; Correlation between some woody species parameter and herbaceous biomass quantities.

Vegetation parameters	Correlation with herbaceous biomass	P_value
Density	-0.467*	0.01
Shannon	0.283*	0.026
Richness	0.248	0.052

* shows that the significant value at ($P< 0.05$)

The Pearson correlation matrix shown that, the density of woody species have a significant negatively relationship with herbaceous biomass quantities ($p<0.05$) and Shannon diversity index have also a positive significant relationship with herbaceous biomass ($p<0.05$) (Table 2), whereas, herbaceous biomass and woody species richness had non-significant relation.Another research done by Riginos` *et al*. (2009) indicates that, isolated individual trees had positive effects on herbaceous biomass, most likely trees could be enrich soil organic matter, but the effects of individual trees could explain the effects of increasing tree density for low biomass of herbaceous production, because the more woody species density leads to depressed of herbaceous biomass productivity.In the area where, trees are widely spaced, many inter-canopy areas are remained entirely unshaded by trees, whereas at high tree densities the shadows cast by individual trees may overlap ,so that grass/herbaceous species in most of the inter-canopy zone is shaded and have a negative relationship with tree densities (Breshears, 2006). Similarly, herbaceous species biomass might be affected by dense tree roots that extend beyond the canopy radius and deplete water or nutrients in the inter-canopy zone (Scholes & Archer, 1997). This study suggests that woody species density can progress markedly reduce the herbaceous biomass, because the more density plant community components was either severely reduced or completely absent of herbaceous species, such effect could become increasingly important at high tree densities. As a result the herbaceous biomass exhibits negatively relationship with the increasing woody species density due to low level of plant and herbaceous species interaction. Adding to the fact that, evapotranspiration is also another factor for increasing herbaceous biomass, and the moderate density of woody species could be contributed to reduce the amount of evapotranspiration that leads to increase the herbaceous biomass .Similar study conducted by Breshears *et al.* (1997); Ludwig *et al.* (2001) low tree density can also facilitate herbaceous biomass by reducing sub-canopy evapotranspiration.

The positive correlation between woody species diversity and herbaceous biomass was due to the diverse plant community that exerts a prevailing influence on the herbaceous biomass quantities. The diverse plant community has diverse characteristics in increasing and/or decreasing in herbaceous biomass(Grime, 1973). Even though, the correlation was very weak, the diverse plant community which provides to increases the herbaceous biomass production might have a better distribution. Consistent result had been reported by Grime (1973) which indicates that, the optimum conservation biodiversity provides high herbaceous biomass production. However, the insignificant correlation between woody species richness and herbaceous biomass suggests that, woody species richness at the initial establishment rate of herbaceous species couldn't be play a crucial role to be correlated more positively. It is also similarly suggested by Oba *et al.* (2001) the direction for the total species richness and biomass were nearly perpendicular, indicating that species richness and biomass was not strongly linearly related. The reason for the productivity of woody species richness for maintaining optimal herbaceous biomass might be sustained by the climatic factor, which causes high inter annual variability of herbaceous biomass. Another study by Grime(1979);Vettaas(1993) indicates that, in the unproductive areas ,external factors such as moisture or other environmental factors are thought to be much more important than internal interactions between the relationship of species richness and herbaceous biomass. In addition to this, the important species in the sites might have in the process of succession.

CONCLUSSION& RECOMMENDATION

The results of this study provided with evidence that, the comparison made between the inner of*A.saligna*canopy and outer segment of *A.saligna* canopy showed that diversity of indigenous woody species and herbaceous biomass was significantly improved in the outer segment of *A.saligna*canopy. As a result, this could be due to high shading condition (close canopy of *A. saligna*) and unfavorable soil conditions under the canopy. The densities of seedlings were significantly improved inouter segment of *Acacia saligna* canopy. However,the saplings of the indigenous woody species are not decreased compared to the inner and outer segment of *Acacia saligna* canopy. The positive and negative significant relation and similarly the positive and negative non-significant relation between some soil physicochemical properties and woody species diversity might be due to the species characteristics and soil nutrient availability of the site. Further study should be needed on soil seed bank, seed physiology and *A.saligna* canopy management options to fill the gap of the study under*Acacia saligna* canopy.

Availability of data and materials;all the data's and materials used in this article are available from the corresponding author.

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